

MANAGING THE PLANT-ANIMAL INTERFACE IN  
TROPICAL LEGUME-GRASS PASTURES

BY

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To my parents Jose and Zoraida  
To my wife Graciela  
To my children Jorge, Diana and Jose Alonso

I love you all

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'Pensacola' bahiagrass (Paspalum notatum Flugge) is the most widely used perennial grass for summer grazing in Florida; however, animal performance from this grass is low. Overseeding bahiagrass (B) pastures with the summer annual legume Aeschynomene americana L. may improve the nutritive value of B pastures but pasture-management practices may influence the quantity of legume in the pasture and in the diet of grazing cattle. Grazing management [rotational (RG) vs. continuous (CG) grazing] of B and bahiagrass-aeschynomene (BA) pastures was studied by investigating the plant-animal interface during grazing of these pastures by cattle. Animal defoliation effects during rotational grazing were studied by sampling both before (BRG) and after (ARG) rotational grazing.

Overseeding B pastures with aeschynomene increased forage crude protein (CP), particularly in the grazing horizon. Herbage mass (HM)

was greater for BRG than for CG. Forage in vitro organic matter digestion (IVOMD) was greater for RG than for CG. Greater grass-leaf percentage in both pasture types and higher legume percentage in BA pastures were found for RG than for CG. In BA pastures, highest forage CP concentration was observed for BRG when legume percentage was highest.

Diet CP concentration of animals on BA pastures was 46% higher than that of animals on B pastures. For RG, diet CP was reduced by animal defoliation so that the level for ARG was similar to that for CG. Animals consumed a diet higher in IVOMD during RG than CG.

Animals on BA pastures obtained a smaller bite weight (BW) than did those on B pastures. Intake per minute (IPM), however, was not different because presence of legume increased bites per minute (BPM), which compensated for the smaller BW. Animals obtained greatest BW when sampling BRG. For ARG, however, BW was reduced to a level similar to that for CG. The IPM was greatest for BRG. A depression in BPM for ARG, however, depressed IPM to a level even lower than that for CG.

Aeschynomene increases forage nutritive value of B pastures. Grazing BA pastures rotationally gives animals the opportunity for a greater intake of forage of higher nutritive value compared to continuous grazing. Greater intake of greater nutritive value forage, however, is obtained only during the first part of the rotational grazing period. Therefore, maximum benefit will be obtained if high-producing animals grazed these pastures first and they are removed to a new paddock before severe defoliation of the legume occurred.

## INTRODUCTION

In Florida, bahiagrass (Paspalum notatum Flugge) comprises most of the land in improved perennial pastures (0.90 million hectares; Chambliss and Jones, 1981). This warm-season perennial grass is widely used because of its excellent persistence under heavy grazing conditions. However, it is of relatively low quality and only moderate to low animal performance can be achieved from it. Summer grazing is important to Florida livestock producers in terms of calf weaning weight and cow body condition. It is imperative, therefore, to increase the quality and utilization of summer grazing pastures. Several other improved grass species such as stargrass (Cynodon nlemfuensis) and limpograss (Hemarthria altissima) have been released over time. Increased amounts of forage and beef per area can be obtained from these new improved grasses if increasing amounts of fertilizer, particularly nitrogen fertilizer, are applied to them.

An alternative to high cost fertilizers for improved tropical pastures has long been the association of grass pastures with legumes. Improved forage nutritive value and animal performance have been achieved when legumes have been introduced (Peacock et al., 1976; Koger et al., 1983a; Kalmbacher and Martin, 1983). Aeschynomene (Aeschynomene americana L.), a summer-growing annual legume, has been successfully utilized in association with different types of grasses in Florida (Brown et al., 1987; Sollenberger et al., 1987b; Rusland et al., 1988).

Pasture nutritive value and animal performance have been improved when it was grown with bahiagrass (Hodges et al., 1974). Given the different growth habits and persistence under grazing of grasses and legumes, grass-legume associations may be difficult to maintain.

Forage plants and cattle are affected by environmental variables such as soil, temperature and rainfall, and by grazing management. Plant and animal responses to these factors, and their interactions, make grazing a very dynamic system. Plants and plant parts of higher nutritive value in the pasture canopy of the pasture may not be readily available to the animal as a consequence of these responses and interactions. Knowledge in this area might indicate the appropriate management of tropical grass-legume pastures to improve forage utilization and animal performance. Plant-animal interface studies offer the opportunity to gain knowledge about the components of a grazing system and their interactions.

Based on the above considerations, a study on managing the plant-animal interface in Pensacola bahiagrass and bahia-aeschynomene pastures was conducted with the following general objectives: a) to determine the effects of rotational and continuous grazing management systems on pasture canopy structure (herbage mass, forage botanical composition and forage nutritive value), diet botanical composition and nutritive value, and animal ingestive behavior, and b) to relate pasture canopy characteristics to animal ingestive behavior.

## LITERATURE REVIEW

### Characteristics of Florida Livestock Production

#### Type of Production System

Cow-calf production is the most important commercial operation in the Florida beef industry (Baker, 1980). Weaned calves are usually marketed from July to September. Summer is a very important period for the beef industry in Florida. During this period the rancher has calves, his major marketing product, to put weight on before weaning time. He also has lactating cows that must gain in body condition during summer. The summer forage growing season offers the opportunity to provide lower cost nutrients to these animals.

#### Pasture Grazing Resources

There are 4.9 million hectares of grassland in Florida, 1.3 million of which are improved perennial grass pastures (Spreen et al., 1985). Of these improved perennial grass pastures, over 0.90 million hectares are of bahiagrass (Paspalum notatum Flugge). There are three cultivars of bahiagrass grown in Florida: Pensacola, Argentine and Paraguay; of which Pensacola is the most popular. Therefore, bahiagrass is the base grass used in improved pastures for summer grazing in Florida (Ocumpaugh, 1978).

### Bahiagrass

Bahiagrass is a warm-season perennial grass forming a dense sod and stolon-root system. The location of the phytomer-producing meristems is at the base of the stolon tip. Because the tip is not removed when clipping or grazing, bahiagrass has a high degree of tolerance to defoliation (Sampaio et al., 1976). Bahiagrass responds to N fertilization with increased forage production and increased forage N concentration (Blue, 1983). Twenty three kilograms or less of applied N, however, might not alter N concentration of the forage (Beaty et al., 1960). It has been suggested that because bahiagrass tolerates a high degree of defoliation its management should be directed more towards its quality rather than its regrowth (Beaty et al., 1968).

The desirable agronomic characteristics of bahiagrass are probably responsible for its extensive use in Florida. Animal performance on bahiagrass pastures, however, is somewhat limited. When compared to other grasses like 'Callie' bermudagrass (Cynodon dactylon), Tifton hybrid bermudagrass 72-81 and Tifton hybrid bermudagrass 72-84, daily gain was lower for Pensacola bahiagrass (0.53, 0.46, 0.52, and 0.38 kg, respectively; Bertrand and Dunavin, 1988). Prates et al. (1974) studied performance of steers on fertilized continuously-grazed Pensacola bahiagrass. Daily gain was 1.0 kg in May but declined to -0.52 kg in September. Forage crude protein (CP) concentration remained above 11% throughout the experiment, but in vitro organic matter digestion (IVOMD) tended to decline as the season progressed. It was suggested that the decreased gain in summer was related to a decline in forage quality and also to problems of rejection and waste due to higher stocking rates in

summer and resulting contamination by feces and urine. In a grazing study from June to September on Argentine bahiagrass, Moore et al. (1969) reported high forage nutritive value with respect to digestion coefficients for dry matter (55.6 to 59.4%) and cellulose (68.7 to 72.7%). Forage digestible protein was inadequate for growing cattle, however. Digestible protein percentages measured in three different periods during that experiment were 3.8, 2.6 and 1.5%, respectively. According to a citation in the same paper (Milford and Haydock, 1965) digestible protein in a subtropical forage should be 3.6% to insure a positive nitrogen balance. Brown and Mislevy (1988) in a clipping study found that increasing maturity reduced CP and IVOMD of Pensacola bahiagrass, Pangola digitgrass (Digitaria decumbens Stent.) and Ona stargrass (Cynodon nlemfuensis var. nlemfuensis) at very rapid rates. They also measured the acid detergent insoluble crude protein (ADICP) which is a measure of the protein that is bound to the fiber components of the cell wall and unavailable to the animal. As a proportion of total CP concentration, ADICP increased from 9.3% at 2 weeks regrowth to 51.3% at 8 weeks regrowth during the summer harvest. Heifers (Pitzer et al., 1988) grazing Pensacola bahiagrass, and calves (Kunkle et al., 1988; Kunkle and Baldwin, 1988) grazing bahiagrass (cultivar not given) pastures had higher daily gains when supplemented with protein. In spite of forage CP levels above 8.3%, animals showed low protein status as indicated by blood urea N. Low protein status of these animals might reflect low levels of available protein in the forage as observed by Moore et al. (1969) and Brown and Mislevy (1988).



The benefit of including legume forages in perennial pastures has been demonstrated by several studies in Florida. Inclusion of winter legumes in forage programs resulted in higher weaning percentage, slightly heavier calves and a lower total cost per cow (Peacock et al., 1976; Koger et al., 1983a; Koger et al., 1983b). Blue (1983) estimated that the value of forage and protein in white clover (Trifolium repens)-Pensacola bahiagrass pastures were equal to those produced by grass with a nitrogen application rate between 224 and 448 kg/(ha year). The benefit of including summer legumes in perennial pastures has also been demonstrated in Florida (Hodges et al., 1974, 1976; Pitman, 1986; Rusland et al., 1988). Inclusion of summer legumes has increased gain per animal, gain per hectare and cow reproductive performance. Ocumpaugh (1978) suggested that overseeding bahiagrass pastures with the summer annual legume, aeschynomene (Aeschynomene americana L), should improve summertime gains.

#### Aeschynomene

Aeschynomene americana has been used in perennial grass pastures in Florida for many years (Hodges et al., 1982), and has been the focus of attention in many studies in Florida. It is the most widely adapted warm-season legume available for grazing in south and central Florida (Hodges et al., 1982; Pitman and Kretschmer, 1984).

Aeschynomene is an annual legume capable of re-establishing itself from seed. Natural reseeding is not very reliable unless management (Chaparro, 1989) and environmental conditions are favorable. Kalmbacher and Martin (1983) suggested that light penetration to the base of the canopy and soil water relations appear to be important in promoting good

legume establishment. Recommendations for establishment of aeschynomene in bahiagrass sod are given by Kalmbacher et al. (1988). After seedlings are 2 or 3 weeks old they recommended fertilizing with 33 kg  $P_2O_5$ /ha and 66 kg  $K_2O$ /ha. Recommended seeding rate for bahiagrass-sod seeding of aeschynomene is 6.7 to 9.0 kg/ha of de-hulled seed. Poor stands of aeschynomene resulted at the Ona Agricultural Research and Education Center when less than the average of 30 mm rain fell during February to May. They recommended choosing the seeding date carefully as the amount of rain before and 2 weeks after seeding aeschynomene is related to stand establishment. Liming before seeding is important if soil pH is below 5.5. Aeschynomene shows tolerance to long-term periods of flooding, but not to soil moisture deficits (Albrecht et al., 1981). When seeded in limpograss pastures, initiation of grazing when aeschynomene was 0.2 to 0.4 m tall as compared to 0.6 and 0.8 m tall resulted in more uniform distribution of total and legume dry matter, higher efficiency of grazing, more vigorous legume regrowth, and a trend toward greater total herbage consumption (Sollenberger et al., 1987b). Hodges et al. (1982) suggested that aeschynomene should be rotationally-grazed because grazing before the plant attains sufficient size results in low productivity.

Aeschynomene had leaves and young stems that contained 24.1% CP (Hodges et al., 1982); however, the coarse stems contained 6.1% CP. Pasture nutritive value was improved when aeschynomene was grown with bahiagrass (Kalmbacher and Martin, 1983). Selectivity for aeschynomene in the pasture and palatability of aeschynomene leaf and fine stems at the top of the plant were demonstrated with fistulated animals

(Sollenberger et al., 1987b). Kretschmer et al. (1986) found in a study with several selected aescynomene introductions, however, that in September as compared to June, IVOMD of Pangola digitgrass was in many instances equal to or greater than that of the associated legume. Sollenberger et al. (1987b) showed that the major contribution of aescynomene to limpograss-aescynomene mixtures was its own CP concentration.

Aescynomene showed adaptation to Florida flatwoods in mixture with bahiagrass pastures under grazing (Pitman and Kretschmer, 1984). Hodges et al. (1974) evaluated eight forage and supplement systems in south-central Florida over a 5-year period. The aescynomene treatment, which consisted of 50% Pangola digitgrass and 50% of a mixture of bahiagrass, and aescynomene, showed average weaned calf percent of 82% compared to 67% for the perennial grass treatment which consisted of pure stands and mixtures of digitgrass, bahiagrass and common bermudagrass. Calf production per cow and calf production per hectare were also higher for the aescynomene treatment than for the perennial grass system. Aescynomene treatments produced intermittent legume grazing of excellent quality from August to November in some but not all years. Failures were due to below-normal June and July rainfall. Gaps in the grazing supply of aescynomene systems required more hay feeding than on the perennial-grass program. They suggested that no more than 25% of a pasture system should be planted to aescynomene. Rusland et al. (1988) found increased daily gains of steers and gain per hectare when aescynomene was grown in limpograss pastures during midsummer through early fall.

Aeschynomene in mixture with tropical grasses improves forage nutritive value and animal performance during the summer season. A good stand of aeschynomene is necessary, however, to achieve the benefits of this legume in mixture with tropical grasses. A good stand of aeschynomene is obtained if recommendations for establishment and management discussed above are followed. It is very important that summer rains are frequent at the time of seeding because this has a great impact on the germination and development of seedlings and, so, on the future of the legume stand.

#### Grazing Systems

Grazing management is the tool used to exercise control of forage utilization. There are basically two systems of grazing management, continuous and rotational. In the continuous grazing system, animals have unrestricted access to a pasture. In the rotational grazing system, pastures are grazed intermittently. A rest period is given to the pasture to allow it to recuperate from defoliation, allowing regrowth and accumulation of herbage for a new grazing period. There has long been a controversy about which grazing system is superior in terms of animal production (Wheeler, 1962). The controversy centered on the role of stocking rate in determining animal production per area. Comparison between these two systems has been done mostly at different stocking rates. Rotationally grazed pastures usually have been stocked higher and so this gave an advantage to rotational grazing. When the two systems were compared at similar stocking rates, not much difference was apparent between systems (Wheeler, 1962). Both management systems

have advantages that might fill practical needs in specific situations. In some cases a combination of the two systems in different periods during the grazing season might be more beneficial in terms of available forage and liveweight gain than the use of one particular grazing system during the entire season (Blaser, 1982). The choice of a particular grazing system depends on factors such as animal type, forage species, period or season of the year, available resources and animal production objectives.

Rotational-grazing systems have been proposed with several modifications (Blaser et al., 1986). One of these is the leader-follower rotational-grazing system. In this modification, animals with higher nutritional demands such as high producing milking cows or growing animals are allowed to graze the paddocks first. These cattle will have the opportunity to obtain the most nutritious components available in the pasture. Once the leader animals graze the more nutritious components in the canopy they are moved to a new paddock. Animals with lower nutritional needs then finish grazing the remaining available forage. Blaser (1982) showed higher milk production and daily gain of leader grazers as compared to follower grazers. On average, there might not be any advantage in milk production or daily gain by using this modified system compared to a straight rotational system (Archibald et al., 1975; Blaser, 1982) and it might even complicate the management of the herd, as suggested by Archibald et al. (1975). Rotational grazing systems are options to improve daily gain or milk production of the most productive animals. Research should provide the most appropriate grazing system for particular situations. Studies on

plant-animal interface might provide some insight into adequate grazing management practices for particular cases.

### Plant-Animal Interface

#### Definition

Plant-animal interface is described as the interactions between forage plants and animals during the act of consumption of forages (Moore and Sollenberger, 1986). In a grazed pasture there are continuing changes in sward and animals and continuing mutual feedback between sward and animals (Riewe, 1980). It is necessary to study the individual components in a grazing system and, also, the mechanisms by which they interact to provide the appropriate management to optimize the animal output from a pasture. The two components of the plant-animal interface are defined under the terms of 'pasture canopy structure' and 'animal ingestive behavior.'

#### Ingestive behavior

Intake of digestible energy is a basic determinant of animal performance (Moore, 1981). Voluntary intake is controlled by distention and metabolic mechanisms. Under grazing, ingestive behavior may override either of the other two mechanisms (Moore and Sollenberger, 1986). Components of animal ingestive behavior include bite weight, rate of biting and grazing time. The product of these three components should give an estimation of herbage intake of grazing animals over a given time interval (Hodgson, 1982). Rate of biting and grazing time are used by animals as compensatory mechanisms in face of decreased bite

weight. The action of these two mechanisms in preventing a decline in intake is, however, limited (Hodgson, 1985). Jaw movements and bites per 100 jaw movements are also described as ingestive behavior mechanisms. Bites per 100 jaw movements indicate amount of forage manipulation occurring during prehension (Moore et al., 1985). Bite weight was shown to be the major factor influencing the intake of herbage by grazing cattle (Chacon and Stobbs, 1976) and animal production (Chacon et al., 1978).

Ingestive behavior may be affected by pasture canopy characteristics (Stobbs, 1973a; Chacon et al., 1978; Moore et al., 1985; Brown et al., 1987). Inaccessibility of the most nutritious components in the pasture canopy might reduce herbage intake (Stobbs, 1975). This indicates that some non-nutritional characteristics of the pasture might influence herbage intake (Hodgson, 1985) and animal performance (Chacon et al., 1978).

#### Canopy structure

Pasture canopy structure includes measurements such as herbage mass, canopy height, botanical composition, and bulk density (weight per unit volume) of total herbage or botanical components. The pasture can be characterized as a whole canopy or further by stratifying the canopy in layers perpendicular to the vertical plane (Stobbs, 1973b). Canopies vary in terms of spatial distribution of botanical components (Hendricksen and Minson, 1985; Sollenberger et al., 1987a). Canopy structure is changed by animal defoliation (Chacon and Stobbs, 1976; Brown et al., 1987), nitrogen fertilization (Stobbs, 1975), forage species (Chacon et al., 1978) and grazing management (Stobbs, 1973b).

Canopy structure influences animal ingestive behavior (Stobbs, 1973a; Stobbs, 1975; Chacon and Stobbs, 1976; Ludlow et al., 1982; Moore et al., 1985; Forbes and Hodgson, 1985; Brown et al., 1987), the diet selected by the animal (Chacon and Stobbs, 1976; Sollenberger et al., 1987a) and the nutritive value of the herbage within the sward (Stobbs, 1973b). Bite weight is also the ingestive behavior mechanism most directly influenced by canopy characteristics, particularly by herbage mass and canopy height (Hodgson, 1985).

#### Plant animal-interface studies on monocultures

Stobbs (1973a) showed the effect of sward canopy structure on bite weight in a series of experiments. Bite weight was calculated from the weight of the collected extrusa obtained with esophageally-fistulated animals and the number of jaw movements recorded with an automatic device. Pastures of fertilized (50 kg N/(ha month) during 2 years) and unfertilized Setaria anceps cv. Kazungula were used. Dry matter yield, plant height, plant bulk density (kg/(ha cm)), nitrogen percentage and the concentration of some minerals in the forage were higher in the fertilized pastures. Mean bite weight by animals grazing the fertilized pastures was larger than by animals grazing the unfertilized pastures (0.39 vs 0.13 g OM/bite).

In a second study, Stobbs (1973a) measured bite weight by animals grazing 5-week old regrowth of the legume siratro (Macroptilium atropurpureum), Kazungula setaria and Pangola digitgrass. Dry matter yields were similar among the three pasture types; however, plant height was greatest in setaria and lowest in digitgrass (26.3 vs 19.4 cm). Plant bulk density was greatest in digitgrass and lowest in setaria (199



vs 149 kg/(ha cm)). In vitro dry matter digestion was greatest in siratro and lowest in setaria (67.5 vs 59.8%). Mean bite weight was smaller for animals grazing siratro pastures than for animals grazing setaria or digitgrass pastures (0.24, 0.38 and 0.34 g OM, respectively).

In a third experiment, pure pastures of Pangola digitgrass and rhodesgrass (Chloris gayana cultivar Pioneer) were treated with the growth regulators gibberellic acid (GA), and 2-chloroethyl-trimethylammonium chloride (CCC; Stobbs, 1973a). The denser canopy of both pastures after treatment with GA resulted in a greater bite weight than that obtained from these same forage species after treatment with CCC. Treatment with CCC increased herbage yield and sward height, and produced erect, stemmy plants with long internodes. Stobbs (1973a) concluded that sward bulk density, a low stem content and a high leaf/height ratio have a major influence upon the bite weight of cattle grazing these pastures. It was estimated that a mean bite weight of less than 0.30 g OM/bite (bite equal to jaw movement in this case) can seriously limit herbage daily intake of 400-kg liveweight cattle.

Pasture maturity affected bite weight (Stobbs, 1973b). Swards of Chloris gayana and Setaria anceps at 2, 4, 6, and 8 weeks of regrowth were compared. Animals had maximum bite weight when pastures were grazed at 4-week regrowth. At this regrowth, pastures had the highest proportion of accessible leaf. At 2-week regrowth, pastures contained 82% leaf, but the yield and density of the herbage was low and bite weight was also low. At 6- and 8-week regrowth, pastures had large herbage yields and bulk densities, but animals had small bite weight. Negative correlations were found between bite weight and yield of

herbage and sward bulk density. Bite weight was positively correlated with leaf percentage in the pasture, and even more highly correlated with leaf percentage in the top layers of the canopy.

In Setaria anceps pastures (Stobbs, 1975), N fertilization at 0, 50 and 100 kg/ha increased bite weight in a linear fashion: 0.29, 0.33 and 0.37 g OM/bite, respectively. The increase in bite weight was related to higher leaf yields and bulk densities. High levels of N fertilization promoted faster rate of growth of 6-week regrowth pastures with no further increase in the bite weight of the animals. Nitrogen fertilization increased leaf yield and bulk densities of these pastures, particularly in the uppermost layers allowing animals to harvest heavy bites. It was suggested that pastures should be grazed before they become mature, not only to obtain a higher nutritive value diet but also to achieve a satisfactory herbage intake by means of the behavioral mechanism. From these studies it is apparent that sward bulk density positively affects bite weight. However, when the increase in sward bulk density is due to plant maturity the relationship becomes negative.

Chacon and Stobbs (1976) studied the effect of progressive defoliation of Setaria anceps pastures on canopy structure and ingestive behavior. At the beginning of grazing periods, animals selected mostly leaf from the top of the canopy. As the quantity of leaf decreased due to defoliation, animals took smaller bites, increased grazing time and increased rate of biting. At later stages of defoliation, grazing time and biting rate declined. Bite weight at later stages of defoliation was extremely low, between 66 to 79 mg OM/bite, which resulted in a low

herbage intake. Leaf yield, leaf percentage and green material bulk density were major sward factors influencing intake by grazing animals.

Swards of N-fertilized Setaria anceps and Digitaria decumbens continuously stocked at 4.3 animals per hectare supported higher animal growth rate, as compared to swards stocked at 6.2 and 8 animals per hectare (Chacon et al., 1978). Steers were able to obtain a heavier bite and select more nutritious plant parts from the top of the sward at the lower stocking rate.

Ludlow et al. (1982) studied the effect of increasing sward density of tropical pastures on bite weight. They also observed the effect of increasing sward density on forage yield as increased density might affect light distribution and canopy photosynthesis. Density of Setaria sphacelata and Digitaria decumbens pastures were modified with the growth regulators GA and CCC. Results indicated that Setaria sphacelata and Digitaria decumbens leaf area densities could be increased to values exceeding those found in temperate pastures without great reductions in yield. Consistent with the results of Stobbs (1973a), increased bite weight was obtained as sward density increased. The conclusion from these results was that there is considerable scope for increasing bite weight and possibly animal production in situations where bite weight (<0.30 g OM/bite) limits daily intake of forage. The researchers suggested also that sward density could be increased by pasture management because density varies with season, stocking rate and frequency of defoliation.

Plant-animal interface studies on grass-legume associations

Moore et al. (1985) studied the effect of different canopy characteristics (canopy height and legume-grass proportions) of limpgrass-aeschynomene pastures on animal ingestive behavior. Steers grazing these pastures responded to increased legume percentage in the upper layer by making more manipulative jaw movements and decreasing rate of biting, but intake per bite did not change. Intake per bite increased as the percentage of green herbage in the upper layer increased. Animals selected a diet greater in legume percentage than that found in the upper layer of the canopy as a result of the manipulative jaw movements prior to biting. Increased canopy height was associated with a larger bite weight.

Brown et al. (1987) studied the plant-animal interface in stargrass and stargrass-aeschynomene pastures rotationally-grazed with 4-week rest periods. They observed a higher biting rate at the beginning of the grazing period with a quadratic decline at the end of the grazing period. They suggested that this effect was due to a reduction in herbage allowance as the grazing period progressed. Biting rate tended to be higher in the grass-legume compared to the grass-alone pastures. In general, differences in biting rate and diet composition were higher between early- and midpoint-grazing than between middle and end of the grazing period. Manipulations, in terms of bites per 100 jaw movements, increased as the grazing period progressed and tended to be higher in grass-alone pastures. Bite weight decreased in both types of pasture from beginning to end of the grazing period. Animals on grass-alone pastures, however, obtained higher bite weight than did those on grass-

legume pastures. The higher biting rate of animals in grass-legume pastures was not enough to compensate for the smaller bite weight. Therefore, animals on grass-legume pastures had a lower intake per minute. Another observation was that at the beginning of grazing periods animals selected for grass leaf in the grass alone-pastures. In grass-legume pastures, however, selection shifted towards legume leaf.

From the plant-animal interface studies reviewed, it is clear that canopy structure is affected by several factors. Some of these factors are forage species, plant maturity, N fertilization, animal defoliation and grazing management. Grazing animals respond to changing canopy characteristics by modifying their ingestive behavior. Some canopy characteristics influence ingestive behavior in a more favorable way towards a greater herbage intake. Increased herbage intake means improvement in animal performance. There is an indication from these studies that canopies with higher bulk densities of grass and/or legume leaf, particularly in the upper layers, are more favorable towards animal ingestive behavior responses that maximize intake. Grazing management of forage species and grass-legume associations to produce those canopy characteristics that favor ingestive behavior for maximum intake needs to be investigated.

The profits of the beef industry in Florida originate from heavier weaning weights and cows in good body condition. These two aspects of economic importance to Florida producers can be improved by increasing intake of forage with a better nutritive value during summer grazing. Bahiagrass is the base of improved pasturage for summer grazing in the state. Aeschynomene is a legume adapted to Florida grasslands that can

improve the nutritive value of bahiagrass pastures. The proper management of bahia-aeschynomene pastures to obtain a canopy structure that maximizes the voluntary intake of herbage needs to be investigated.

It is apparent from this review that studying the plant-animal interface might have some practical implications. It might give some knowledge about the most adequate pasture and animal management practices for specific situations. Knowing the nutritive value and forage availability of a pasture is not enough to estimate animal performance. Study of the plant-animal interface goes a step further and characterizes the mechanisms and relationships between the plant and animal components of the system that might be important to animal performance.

## MATERIALS AND METHODS

### General Description of Location

Pastures of Pensacola bahiagrass (Paspalum notatum Flugge) and Pensacola bahiagrass-aeschynomene (Aeschynomene americana L.) were grazed from August to November, 1986 at the Ona Agricultural Research and Education Center near Ona, in Hardee County. The experimental site was located at 82° 55' W longitude and 27° 26' N latitude in south central Florida. Pastures were on a sandy siliceous hyperthermic Ultic Haplaquod (Pomona fine sand) soil. Soil pH was 5.5. Total precipitation for 1986 was 1393 mm, which was 36 mm above the 1942-86 average of 1357 mm. Of this precipitation 1081 mm fell between June and November. The average minimum and maximum temperatures between June and November were 16.6 and 32.6° C, respectively (Stephenson and McCloud, 1987).

### Pastures

#### Pasture Establishment

Pastures were located on an established stand of bahiagrass in a total area of about 0.50 ha. The entire area was fertilized June 1, 1986 with 12 kg P/ha and 46.5 kg K/ha. An area of 0.26 ha, to be used as pure bahiagrass pastures, was fertilized on June 10 with 30 kg N/ha using  $\text{NH}_4\text{NO}_3$ . On June 11, an area of 0.20 ha, to be used as grass-

legume pastures, was seeded with aescynomene at the rate of 9 kg/ha of unscarified seed. After aescynomene seeding, grass-legume pastures were clipped weekly to an 8-cm stubble until July 3 when the legume became established for successful association with the grass. Separate paddocks were fenced for the following grazing management by pasture type treatments:

- 1) continuously-grazed bahiagrass pastures (0.08 ha)
- 2) continuously-grazed bahiagrass-aescynomene pastures (0.05 ha)
- 3) rotationally-grazed bahiagrass pastures (0.05 ha)
- 4) rotationally-grazed bahiagrass-aescynomene pastures (0.05 ha)

Each of these pasture type-grazing management combinations was replicated twice.

#### Pasture management

Pastures were managed to simulate continuous and rotational grazing systems. Continuous grazing was established by varying the stocking rate to maintain a 20-cm forage stubble height in the pastures at all times. Animals were removed from the continuously-grazed pastures when the target stubble height was reached and returned when the pasture height was about 25 cm. Rotational grazing was established by allowing a 4-week rest period followed by a grazing period that lasted until the forage stubble height reached 20 cm. Crossbred steers averaging 378 kg body weight were used to graze the paddocks as needed. Steers were kept in a bahiagrass pasture near the experimental site and were chosen at random when needed.



### Sampling and Laboratory Procedures

Pasture canopy and animal ingestive behavior measurements were obtained. Samples were collected for 4 cycles based on the grazing cycle of the rotational grazing system. A grazing cycle consisted of a 4-week rest period and a 3- to 7-day grazing period. Each cycle corresponded approximately to the months of August, September, October and November for cycles 1, 2, 3, and 4, respectively (table 1).

In rotationally-grazed pastures, canopy samples were obtained just prior to initiation of the grazing period (before rotational grazing, BRG) and just after conclusion of the grazing period (after rotational grazing, ARG). Immediately after canopy measures were obtained, esophageally-fistulated steers were used for the collection of extrusa and measurements of ingestive behavior. Sampling this way permitted the investigation of animal defoliation effects during the grazing period in the rotationally-grazed pastures. Continuously-grazed pastures were sampled only once each cycle. Pasture canopy was sampled and animal ingestive behavior measured on dates similar to those when rotationally-grazed pastures were sampled (table 1).

#### Forage sampling and separation

A double sampling technique was implemented because uneven grazing was expected in these pastures. The double sampling technique included whole canopy visual estimations on 35 sites per pasture, of which 5 sites were physically sampled. Visual estimations were made of herbage mass (HM, kg DM/ha) and percentages of grass, legume and other (weeds and dead) herbage. The 5 sites which were physically sampled were

Table 1. Sampling dates for canopy and ingestive behavior measurements

Cycle	Month	Bahia grass			Bahia-aeschynomene		
		CG <sup>a</sup>	BRG <sup>b</sup>	ARG <sup>c</sup>	CG	BRG	ARG
1	August	11	11	16	23	18	23
2	September	22	14	18	21	21	26
3	October	20	20	22	26	26	29
4	November	21	19	23	26	25	29

Note: Numbers in table main body are days of the month

<sup>a</sup> CG=continuous grazing

<sup>b</sup> BRG=before rotational grazing

<sup>c</sup> ARG=after rotational grazing

selected to cover the range in HM and percentages of grass and legume observed in the pastures. The samples were clipped in 10 cm layers. A half-square meter quadrat mounted in a frame was used. The quadrat could be adjusted vertically every 10 cm. Forage in the first 10 cm above ground level was not sampled. The maximum number of layers obtained from these pastures was 4; however, 3 or 4 layers in a pasture were not common. For statistical analysis by layer, the uneven number of layers in a pasture posed the problem of empty cells. In order to evaluate treatment effects between layers, layers 3 and 4 when present were pooled together with layer 2. Hereafter, the two layers used to describe the pasture canopy are referred to as bottom layer for layer 1, and grazing horizon for the pooled upper layers. The bottom layer was that between 10 and 20 cm above ground level and the grazing horizon was that over 20 cm above ground level. Layer data for cycle 1 were omitted from statistical analysis because, after pooling data for the grazing horizon, empty cells still existed.

Clipped forage samples were stored at 0° C immediately after collection until hand separated. Samples were manually separated into grass leaf and stem, legume leaf and stem, dead material and weeds. If forage from a layer weighed 50 g or less for bahiagrass pastures or 75 g or less for bahia-aeschynomene pastures, forage in the entire layer was separated into its botanical components. When layer weights were 50 to 100 g for bahiagrass pastures and 75 to 150 g for bahia-aeschynomene pastures, 50 and 75 g were separated, respectively. When layer weights were larger than 100 g for bahiagrass pastures or 150 g for bahia-aeschynomene pastures, one half was separated, but this was never more

than 100 g and 150 g for bahiagrass and bahia-aeschynomene pastures, respectively.

For bahiagrass samples, leaf sheath and leaf blade were included in the leaf fraction. The bahiagrass stem fraction included only the reproductive stem and seeds when present. For aeschynomene the whole composite leaf was included in the leaf fraction. When legume pods and seeds were present, they were included in the stem fraction.

Once separated, plant fractions were placed in a forced-air oven at 60° C for 72 hr, then equilibrated to atmospheric moisture at room temperature, and weighed. In order to have enough sample for laboratory analyses, dry plant fractions were composited before grinding. Criteria for compositing was based on observations in the field at the time of sampling. Canopy layers were numbered from bottom to top. Two canopy layers from different sites were combined if they occupied the same horizontal space and if both sites were grazed or both were not grazed. If nongrazed, top layers were composited together independently of layer number. If the site was non-grazed and had only one layer, then forage in that layer was placed into the top layer composite, otherwise it was always included in the bottom layer composite. Intermediate layers were composited accordingly after selecting the top and bottom layers as described. Composites were then ground through a 1-mm screen in a Wiley mill.

Dry matter (DM), organic matter (OM) and crude protein (CP) analyses were conducted on the composited samples following AOAC (1975) procedures. In vitro OM digestion was determined by a modification (Moore and Mott, 1974) of the Tilley and Terry (1963) technique.

#### Correction of visually estimated data

Actual whole canopy data were regressed on visual estimates to generate equations to correct the average of the 35 visual estimations. The best equations were selected based on the criteria of a low standard error of the mean and a high coefficient of determination. Plotting of residuals against predicted values, and the overlay of actual vs visual, and predicted vs visual plots were used to study the possibility of under- or over-estimation by the equation. Analysis of residuals and the studentized residual statistics were used as criteria for deleting outliers when needed.

#### Correction of layer data

Layer data were corrected before statistical analysis of the stratified pasture canopy was conducted. Because sites for canopy measurement were chosen to cover the range in canopy structure, layer data from these sites may not have been representative of the pasture. A formula relating adjusted and unadjusted whole canopy and layer values was used (Sollenberger et al., 1987a) to correct the layer data. This formula is based on the assumption that the ratio between an adjusted whole canopy (AWC) mean, which refers to the adjusted average of the 35 visual estimations per pasture, and an unadjusted whole canopy (UWC) mean, generated from the average of the 5 actual clippings, is proportional to the ratio between an adjusted layer fraction (ALF, unknown) mean, and a corresponding unadjusted layer fraction (ULF), which refers to the fraction layer values from the 5 actual clippings. Then, ALF is solved as follows:  $ALF = (AWC/UWC) * ULF$ .

Laboratory analysis values obtained from the composited layer samples described above were applied to the data in the following way. Dry matter and OM were applied to the air-dry weight raw data (ULF). Crude protein and IVOMD values were applied to the OM, ALF weights. Then, from the total CP, in vitro digestible OM (IVDOM) and OM by layer, the percentage of adjusted layer CP and IVOMD were calculated. Whole canopy CP and IVOMD were calculated by summing the total CP and IVDOM by weight in all layers and obtaining the proportion of these relative to the total whole canopy OM.

#### Ingestive behavior measurements

Ingestive behavior measurements obtained included bites per minute (BPM), jaw movements per minute (JPM), and intake per minute. Four esophageally-fistulated steers (average weight 410 kg) were used per pasture to obtain ingestive behavior measurements. Animals were kept on a bahiagrass pasture near the experimental site and were fasted overnight before being used for sampling. Sampling was carefully planned to avoid any biased pattern in the sampling rotation of animals between pastures. On the sampling day, cattle were allowed to graze the pasture for 15 minutes. During the sampling period, total bites were counted with a hand tally counter. A bite was defined as the sound of forage being severed at the moment of biting. Bites per minute were calculated from the total number of bites taken during the 15-minute sampling period. Total jaw movements were counted with a digital microswitch counter which was connected to an elastic band placed around the animals muzzle. The opening and closing of the animal's mouth opened and closed an electric circuit which was recorded with a digital

device. Jaw movements per minute were calculated from the total jaw movements during the 15-minute sampling period. From the BPM and JPM the number of actual bites per 100 jaw movements (B100JM) were calculated; this measurement was an indication of the degree of manipulation the animal exerted in order to obtain a bite of forage. Extrusa samples were collected during the sampling period. The diet sample was collected into a canvas bag fitted with a screened bottom to allow drainage of saliva.

The total extrusa was weighed as collected, and a representative sub-sample of about 250 g was placed in a forced-air oven at 60° C for 72 hr, then allowed to equilibrate to atmospheric moisture at room temperature, weighed and ground through a 1-mm screen in a Wiley mill. Laboratory DM, OM, CP and IVOMD were determined on extrusa samples as described above. Values for laboratory DM and OM were applied to the calculated total oven-dried extrusa weight. From the total number of bites and weight of extrusa collected during the sampling period, the bite weight (BW) was calculated. From BPM and BW, intake per minute (IPM) was calculated.

Another representative sub-sample of about 250 g from the fresh collected extrusa was taken and immediately stored at 0° C. Diet botanical composition was determined from this second extrusa sub-sample. For this determination, a double sampling technique was used. Visual estimations were made by a microscope hit technique. For this, a 10 to 15 g sample was washed gently with tap water in a sieve until the drain water was clear. The sample was then uniformly distributed in a 16 x 45 x 5 cm tray which was about half filled with water. A

transparent plastic sheet with 50 hits (dot marks) was fitted in the tray on top of the water and sample. Hits were organized into 2 rows of 5 ( $2\text{ cm}^2$ ) with 5 hits each (marks at 4 corners and center of a field). Plant parts under each of 50 hits were identified using a 6.3X stereoscope and entered into a computer as a numerical code. Plant parts identified were grass leaf and stem, legume leaf and stem, weeds and dead herbage. The same procedure used in the hand separation of forages, with reference to plant parts included in each botanical fraction, was followed for extrusa botanical composition. Samples were randomized for analysis in each of two runs. The second run did not begin until the first run for all samples was completed. Once the two runs were completed the codified hit data were processed by frequency, transpose and summary procedures in SAS-PC version 6 (SAS, 1987) for plant part percentage calculation.

The mean of the two runs for each sample was calculated and the samples were separated in 10 percent-unit groups based on grass leaf percent. Twenty-five percent of the total number of samples were randomly selected, with similar number of samples from each group. These samples were completely hand separated for the same fractions as in the visual estimations. For this hand separation a 5 or 7 g extrusa sample was used from bahiagrass pastures or bahia-aeschynomene pastures, respectively. For this separation the same 6.3X stereoscope described above was used. Portions of the sample were placed in small aluminum pans which contained a small amount of water. The separated plant parts from a given sample were placed into aluminum pans and dried in a forced air oven at  $105^{\circ}\text{C}$  for 72 hr. Following this, samples were



placed into a desiccator for 2 hr and then weighed. Using the frequency procedure with the weight option and the transpose procedure of SAS-PC version 5.6 (SAS, 1987) the weight data were converted to percentages. The extrusa visual estimations were then corrected with the linear regression parameters obtained by regressing the hand separated values against the corresponding visual values. Selection of the best regression equation was based on the same criteria as mentioned above for canopy double sampling technique. This procedure was conducted separately for extrusa samples from bahiagrass and bahia-aeschynomene pastures; however, the correction for both type of extrusa samples was based on grass leaf percentage.

#### Statistical Analysis

Main effects for this experiment included pasture type (bahiagrass vs bahia-aeschynomene), grazing management (rotational vs continuous grazing; rotational included before and after grazing measurements to study the effect of animal defoliation), canopy layer (bottom vs grazing horizon), and cycle (August vs September vs October vs November). The experiment was arranged in a split-split-plot design or in a split-plot design depending upon inclusion of canopy layer in the model (Snedecor and Cochran, 1980). The primary objective of taking repeated measurements over the season was to increase the accuracy of the study with a larger number of observations rather than to study seasonal effects. Most cycle interactions appeared to be related more to inconsistent variations between sampling periods than to a consistent

seasonal trend. So, only those cycle main effects or cycle interactions that had a biological meaning were discussed.

For whole pasture canopy, diet composition and animal ingestive behavior data, pasture type and grazing management were included in the main plot with replicate nested within pasture type and with grazing management as the error term for main plot. Cycle was included as the subplot and the remainder as the error term. These data were analyzed using the General Linear Models procedure (GLM) of SAS-PC version 6 (SAS, 1987).

For pasture layer data, layer was included as the first sub-plot with replicate times layer nested within pasture type and grazing management as the error term. Cycle was included as the second sub-plot with remainder as the error term. The effects of interest from this analysis were those where layer was present. These data were analyzed using the analysis of variance procedure (ANOVA) in SAS-PC version 6 (SAS, 1987). To further study the layer data analysis within layer was performed. Special interest in this analysis was when the between layers analysis indicated significant interactions.

Contrasts for pair-wise comparisons and polynomial effects were performed. For means multiple comparisons, the Student-Newman-Keuls (Snedecor and Cochran, 1980) procedure at the 10% probability was used. Simple correlations were performed to study relationships between canopy characteristics and animal ingestive behavior.

## RESULTS AND DISCUSSION

### Pasture Canopy Structure and Forage Nutritive Value

#### Whole Pasture Canopy

Analyses of variance for whole canopy data are in tables 22 through 24, appendix.

#### Pasture type main effects

Whole canopy herbage mass (HM) was greater in bahia-aeschynomene than in bahiagrass pastures ( $P=.006$ , table 2). Because canopy height did not differ ( $P=.762$ ) between pasture types, the difference in HM was due to a more dense canopy in grass-legume pastures. Whole canopy forage IVOMD was greater in bahiagrass compared to bahia-aeschynomene pastures ( $P=.054$ ; table 2). The average IVOMD of legume stem and grass leaf were 41.9 and 53.7% (not shown in table), respectively.

Differences in whole canopy forage IVOMD between the two pasture types may have been due to the presence of legume stem, particularly in the bottom layer, which was less digestible than was bahiagrass leaf.

#### Grazing management main effects

Herbage mass was greater before rotational grazing than during continuous grazing ( $P<.10$ ; table 3). The HM after rotational grazing, was not different from that during continuous grazing ( $P>.10$ ). A

Table 2 Least squares means for the effect of pasture type (bahiagrass (B) and bahia-aeschynomene (BA)) on whole canopy herbage mass, and in vitro organic matter digestion (n=24)

Item <sup>a</sup>	Pasture		Statistics <sup>b</sup>	
	B	BA	SEM	P
HM, kg OM/ha	969.4	1316.5	59.14	.006
IVOMD, %	49.3	46.2	0.91	.054

<sup>a</sup> HM=herbage mass; OM=organic matter; IVOMD=in vitro organic matter digestion

<sup>b</sup> SEM=Standard error of mean; P=probability value

Table 3 Least squares means for the effect of grazing management (before (BRG) and after (ARG) rotational grazing, and continuous grazing) on whole canopy herbage mass, height and in vitro organic matter digestion (n=16)

Item <sup>a</sup>	Rotational			Statistics <sup>b</sup>	
	BRG	ARG	Continuous	SEM	P
HM, kg OM/ha	1494.0 <sup>c</sup>	871.5 <sup>d</sup>	1063.4 <sup>d</sup>	72.43	.002
Height, cm	28.8 <sup>c</sup>	17.6 <sup>d</sup>	18.9 <sup>d</sup>	0.62	.001
IVOMD, %	50.9 <sup>c</sup>	47.8 <sup>d</sup>	44.7 <sup>e</sup>	1.11	.021

<sup>a</sup> HM=herbage mass; OM=organic matter; IVOMD=in vitro organic matter digestion

<sup>b</sup> SEM=standard error of mean; P=probability value

<sup>cde</sup> Means in a row with different letters are different (P<.10)

similar trend was observed with respect to canopy height (table 3). The canopy was taller before rotational grazing than during continuous grazing ( $P < .10$ ). As expected, there was no difference in canopy height when sampled after rotational grazing than during continuous grazing. Pastures under rotational and continuous grazing systems were grazed to a 20-cm stubble height. Although the actual canopy height obtained was slightly lower than planned it was still consistent with the objective of similar canopy height at the end of rotational grazing compared to that in continuously-grazed pastures.

Whole canopy forage IVOMD of continuously-grazed pastures was lower than that of rotationally-grazed pastures ( $P < .10$ ; table 3). Herbage mass, canopy height, and forage IVOMD were reduced as an effect of animal defoliation during rotational grazing ( $P < .10$ ; table 3).

#### Pasture type-grazing management interactions

Canopy characteristics such as percentages of grass, legume, other herbage, and forage CP responded differently to grazing management and animal defoliation depending on pasture type. Grass percentage in the whole canopy of bahia-aeschynomene pastures was less than that in bahiagrass pastures due to the presence of legume in bahia-aeschynomene pastures ( $P = .001$ ; table 4). Grass percentage in bahiagrass or bahia-aeschynomene pastures was lower in continuously- than in rotationally-grazed pastures ( $P < .10$ ). Grass percentage in rotationally-grazed bahiagrass pastures was reduced due to animal defoliation during the grazing period ( $P < .10$ ). In bahia-aeschynomene, however, this reduction did not occur. More legume was found in bahia-aeschynomene pastures before rotational grazing than when the pastures were grazed

Table 4 Least squares means for the interaction of grazing management (before (BRG) and after (ARG) rotational grazing, and continuous grazing (CG)) and pasture type (bahia grass (B) and bahia-aeschynomene (BA)) on whole canopy botanical composition, and crude protein (n=8)

Item <sup>a</sup>	B			BA			Statistics <sup>b</sup>	
	BRG	ARG	CG	BRG	ARG	CG	SEM	P
Grass, %	78.2 <sup>c</sup>	68.9 <sup>d</sup>	51.7 <sup>e</sup>	44.7 <sup>c</sup>	42.6 <sup>c</sup>	37.8 <sup>d</sup>	1.38	.001
Legume, %				22.2 <sup>c</sup>	11.9 <sup>d</sup>	10.4 <sup>d</sup>	2.53	.081
Other, %	21.8 <sup>e</sup>	31.1 <sup>d</sup>	48.3 <sup>c</sup>	33.1 <sup>d</sup>	45.5 <sup>c</sup>	51.8 <sup>c</sup>	1.84	.061
CP, %	7.8	7.3	7.3	10.2 <sup>c</sup>	7.7 <sup>d</sup>	7.9 <sup>d</sup>	0.40	.080

<sup>a</sup> Other-weeds and dead material; CP=crude protein

<sup>b</sup> SEM=standard error of mean; P=probability value; Statistics for legume refer to management main effect

cd Means in a row within pasture type with different letters are different (P<.10)

continuously ( $P < .10$ ; table 4). Animal defoliation during rotational grazing reduced the proportion of legume in the canopy to levels found in continuously-grazed pastures (table 4). Other percentage, which included weeds and dead material, was greater in bahia-aeschynomene than in bahiagrass pastures when rotationally-grazed. No difference between pasture type for this botanical fraction was apparent when pastures were grazed continuously. Other percentage was greater under continuous than under rotational grazing management in bahiagrass pastures ( $P < .10$ ). Other percentage in bahia-aeschynomene pastures, however, was greater under continuous than for the before rotational grazing sampling ( $P < .10$ ) but similar to that after rotational grazing. An increase in other percentage was observed as an effect of animal defoliation in both pasture types ( $P < .10$ ) indicating that animals were selecting against weeds and dead material.

Bahia-aeschynomene pastures had higher forage CP than did bahiagrass pastures only before rotational grazing (Table 4), probably because of higher proportion of legume in the canopy at this time. Forage CP in bahiagrass pastures was not affected by grazing management or animal defoliation.

In rotationally-grazed bahia-aeschynomene pastures forage CP was higher than that during continuous grazing only before rotational grazing ( $P < .10$ ; table 4). The effect of grazing on CP reflected the reduction of legume due to animal defoliation during rotational grazing to levels similar to those in continuously-grazed pastures. Therefore, forage CP in bahia-aeschynomene pastures followed the response of legume to grazing management and animal defoliation. The levels of whole



pasture CP observed in all pastures, except for bahia-aeschynomene before rotational grazing, are on the border line of 7% suggested by Milford and Minson (1965) to be the critical level below which animals might experience depressed voluntary intake of dry matter due to protein deficiency.

#### Cycle effects

Legume percentage increased consistently during the season with a maximum in October and then dropped drastically in November ( $P < .10$ , table 5). Rusland et al. (1988) observed in aeschynomene-limpograss pastures that maximum aeschynomene percentage occurred in October. The drastic decrease in legume percentage in November is probably related to flowering, seed development, and loss of leaf tissue. These results and other studies (Hodges et al., 1982; Sollenberger et al., 1987b) suggest that high quality forage is provided by aeschynomene from mid to late summer.

Forage IVOMD decreased steadily across the season in both types of pasture ( $P < .10$ ; table 5). The decrease appeared to be at an increasing rate as the season progressed. Sollenberger et al. (1987b) observed a decline in forage IVOMD in bahiagrass pastures from June to October. A decrease in aeschynomene IVOMD as the plant matured has also been reported (Mislevy and Martin, 1985).

#### Canopy Layers

Analyses of variance of canopy layer data are in the appendix: tables 25 through 28 for combined layer responses, tables 29 through 31

Table 5 Least squares means for the effect of cycle on whole canopy legume percentage in bahia-aeschynomene pastures (n=6) and in vitro organic matter digestion in all pastures (n=12)

Item <sup>a</sup>	Cycle <sup>b</sup>				Statistics <sup>c</sup>	
	1	2	3	4	SEM	P
Legume, %	8.6 <sup>f</sup>	14.0 <sup>e</sup>	25.1 <sup>d</sup>	11.7 <sup>e</sup>	1.05	.001
IVOMD, %	52.5 <sup>d</sup>	50.0 <sup>e</sup>	46.6 <sup>f</sup>	42.1 <sup>g</sup>	0.88	.001

<sup>a</sup> IVOMD=in vitro organic matter digestion

<sup>b</sup> Cycles correspond to August, September, October and November, respectively

<sup>c</sup> SEM=standard error of mean; P=probability value

<sup>d,f,g</sup> Means in a row with different letters are different (P<.10)

for within grazing horizon responses, and tables 32 through 34 for within bottom layer responses.

#### Grazing management by layer interactions

There was a grazing management by layer interaction for dead material percentage across both pasture types ( $P=.015$ ; table 6). Dead material percentage was greater in the bottom layer than in the grazing horizon at the beginning of the grazing period in rotationally grazed pastures ( $P=.014$ ). After rotational grazing and during continuous grazing, however, there were no differences in dead material percentage between layers. Dead material percentage was higher in both layers when the pastures were grazed continuously than when they were grazed rotationally ( $P<.10$ ). Dead material percentage increased in both layers as an effect of animal defoliation during rotational grazing ( $P<.10$ ). The increase in dead material percentage during rotational grazing was particularly high in the grazing horizon where there was a 100% increase as compared to only a 30% increase in the bottom layer. These results reflect the removal of green herbage by the animal particularly at the top of the canopy. The defoliation process is much easier at the top than at the bottom of the canopy where dead material may inhibit grazing. Therefore, it appears that grazing animals discriminate against dead material in the canopy and as the canopy is grazed it becomes even more difficult to obtain green material. Animals may spend more time searching for green herbage at the end than at the beginning

Table 6 Least squares means for the interaction of grazing management (before (BRG) and after (ARG) rotational grazing, and continuous grazing (CG)) and canopy layer on dead material percentage across all pastures (n=12) and on legume leaf and stem percentage in bahia-aeschynomene pastures (n=6)

Item <sup>a</sup>	Layer <sup>b</sup>	Management (M)			SEM <sup>c</sup>			pd	
		BRG	ARG	CG	M	M*Layer	M	M	M*Layer
Dead material, %	2	13.0 <sup>g</sup>	26.1 <sup>f</sup>	37.1 <sup>e</sup>	1.33	0.92	.001	.015	
	1	21.9 <sup>g</sup>	28.4 <sup>f</sup>	39.0 <sup>e</sup>	1.55		.001		
PDIFF		.014	.247	.302					
Legume leaf, %	2	14.8 <sup>d</sup>	3.8 <sup>e</sup>	6.0 <sup>e</sup>	1.05	0.42	.010	.001	
	1	2.3	0.9	2.4	0.71		.396		
PDIFF		.001	.017	.009					
Legume stem, %	2	28.6 <sup>d</sup>	19.4 <sup>e</sup>	12.0 <sup>f</sup>	1.88	1.82	.019	.028	
	1	14.6	12.6	8.7	1.60		.169		
PDIFF		.012	.078	.289					

<sup>a</sup> PDIFF=probability of the difference

<sup>b</sup> 1=Bottom layer 10-20 cm above ground level; 2= grazing horizon over 20 cm above ground level

<sup>c</sup> SEM=standard error of mean; Values for M refer to the statistics for the analysis within layer; Values for M\*Layer refer to the statistics for the interaction between management and canopy layer

<sup>d</sup> P=probability

<sup>e</sup>g Means in a row with different letters are different (P<.10)

of the grazing period because they have to be more selective in order to obtain similar amounts of green material. The response of dead material percentage in the canopy layers to grazing management and animal defoliation is similar to the response of other material observed in the whole canopy of bahiagrass pastures (table 4).

Legume leaf percentage was higher in the grazing horizon than in the bottom layer of bahia-aeschynomene pastures independent of grazing management and animal defoliation ( $P<.02$ ; table 6). The difference between the layers was particularly high before rotational grazing. The percentage of legume leaf in the grazing horizon before rotational grazing was higher than that during continuous grazing ( $P<.10$ ). No difference in grazing horizon legume leaf percentage was found between after rotational grazing and continuous grazing. Legume leaf in the grazing horizon was reduced by animal defoliation during rotational grazing ( $P<.10$ ). No differences in legume leaf percentage were observed in the bottom layer due to grazing management and animal defoliation. These results on legume leaf percentage show the benefit of rotationally-grazing bahia-aeschynomene pastures in terms of the accumulation of legume leaf at the top of the canopy, and suggest a high palatability of legume leaf by the animal. A similar observation was made by Sollenberger et al. (1987a), in aeschynomene-limpograss pastures.

There was an interaction between grazing management and canopy layer on legume stem percentage ( $P=.028$ ; table 6). Legume stem percentage was higher in the grazing horizon than in the bottom layer of rotationally-grazed bahia-aeschynomene pastures ( $P<.10$ ). There was no

difference, however, in legume stem percentage between the canopy layers of continuously grazed bahia-aeschynomene pastures. An effect of grazing management and animal defoliation on legume stem was found only in the grazing horizon ( $P=0.019$ ). Bahia-aeschynomene pastures under continuous grazing had a lower percentage of legume stem than did those under rotational grazing ( $P<0.10$ ). Legume stem in the grazing horizon was reduced due to animal defoliation during rotational grazing ( $P<0.10$ ). Higher consumption of legume stem from the grazing horizon as compared to the bottom layer might be related to differences in nutritive value of the legume stem. Legume stem in the top of the canopy appeared to be more tender and finer than that in the bottom layer and probably more palatable to the animal. Average IVOMD of legume stem in the bottom layer was lower than in the grazing horizon (38.1 and 45.6%, respectively; not shown in table). Sollenberger et al. (1987a) observed a high palatability of aeschynomene by animals grazing limpgrass-aeschynomene pastures. Another possible reason for stem consumption might be that in grazing legume leaf the animal is forced to consume some legume stem. The ratio of legume leaf percentage to legume stem percentage in the grazing horizon was 0.52 and 0.20 for before and after rotational grazing, respectively, showing animal selection for legume leaf rather than for legume stem. Considering legume leaf and legume stem together the percentage of legume in the grazing horizon was 43.4, 23.2, and 18% for before and after rotational grazing and continuous grazing, respectively. Comparing these values to the corresponding values for legume percentage in the whole canopy (table 4), the percentage of legume at the top of the canopy was about twice as high as

that in the whole canopy. Legume leaf/stem ratio decreased from grazing horizon to bottom layer, being 0.52 and 0.16, 0.20 and 0.10, and 0.50 and 0.27 for before and after rotational grazing and continuous grazing, respectively. Similar observations were made by Moore and Sollenberger (1986) in limpograss-aeschynomene pastures.

#### Pasture type, grazing management and canopy layer interactions

Herbage mass was influenced by interactions between pasture type and grazing management ( $P=.038$ ) and between pasture type and canopy layer ( $P=.005$ ), but there was no three-way interaction ( $P=.877$ ; table 7). There was a type by management interaction in the grazing horizon ( $P=.005$ ) but not in the bottom layer ( $P=.180$ ). In bahiagrass pastures the grazing horizon had more herbage mass under continuous than under rotational grazing ( $P<.10$ ), perhaps because of mature grass accumulation in areas rejected by animals in continuously-grazed bahiagrass pastures. In bahia-aeschynomene pastures, however, there was more herbage mass in the grazing horizon at the beginning of rotational grazing than in grazing horizon of continuously grazed pastures ( $P<.10$ ). This result is probably related to the high amounts of aeschynomene present at the top of the canopy at the beginning of rotational grazing. Herbage mass in the grazing horizon of bahiagrass and bahia-aeschynomene pastures was reduced by animal defoliation ( $P<.10$ ).

The proportion of grass leaf in the canopy layers was influenced by grazing management, pasture type and canopy layer ( $P=.007$ ; table 7). In bahiagrass pastures no difference in grass leaf percentage was found

Table 7 Least squares means for the interaction of pasture type, grazing management (before (BRG) and after (ARG) rotational grazing, and continuous grazing (CG)) and canopy layer on herbage mass and grass leaf percentage (n=6)

Item <sup>a</sup>	Layer <sup>b</sup> (L)	Pasture (T) * Management (M)						Statistics <sup>c</sup>			
		Bahia-grass			Bahia-aeschynomene			SEM		P	
		BRG	ARG	CG	BRG	ARG	CG	T*M	T*M*L	T*M	T*M*L
HM, kg OM/ha	2	371.0 <sup>e</sup>	235.6 <sup>f</sup>	521.6 <sup>d</sup>	611.7 <sup>d</sup>	480.8 <sup>e</sup>	440.5 <sup>e</sup>	37.27	47.03	.005	.877
	1	776.6	607.3	854.0	1267.1	1048.4	1033.3	77.82			.180
PDIFF		.002	.002	.003	.005	.007	.007				
Grass leaf, %	2	69.7 <sup>d</sup>	55.0 <sup>e</sup>	40.5 <sup>f</sup>	22.8	27.0	22.9	2.60	1.14	.004	.007
	1	71.4 <sup>d</sup>	63.1 <sup>e</sup>	44.4 <sup>f</sup>	43.7 <sup>d</sup>	38.3 <sup>e</sup>	35.4 <sup>e</sup>	1.84			.005
PDIFF		.310	.010	.068	.001	.008	.006				

<sup>a</sup> HM=herbage mass; OM=organic matter; PDIFF=probability of the difference

<sup>b</sup> 1=bottom layer 10-20 cm above ground level; 2=grazing horizon over 20 cm above ground level

<sup>c</sup> SEM=standard error of mean; P=probability; Values for T\*M refer to the statistics for the interaction between pasture type and grazing management; Values for T\*M\*L refer to the statistics for the interaction between pasture type, grazing management, and canopy layer

def Means in a row within pasture type with different letters are different (P<.10)



between layers at the beginning of rotational grazing. After rotational grazing ( $P=.010$ ) and under continuous grazing ( $P=.068$ ), however, the bottom layer had higher grass leaf percentage than did the grazing horizon, indicating a more intense defoliation of upper layers by the animals. In bahia-aeschynomene pastures the percentage of grass leaf in the bottom layer was higher at all times than that in the grazing horizon ( $P<.01$ ), no doubt reflecting the presence of aeschynomene in the top of the canopy.

In both layers of bahiagrass pastures, continuously-grazed pastures had lower grass leaf percentage than did rotationally-grazed pastures ( $P<.10$ ; table 7). In bahia-aeschynomene pastures a difference between the two grazing systems occurred only in the bottom layer with lower grass leaf percentage under continuous grazing than before rotational grazing ( $P<.10$ ). No difference in grass leaf percentage was observed between the continuous and after rotational grazing in the bottom layer of bahia-aeschynomene pastures. Grass leaf percentage in both layers of bahiagrass pastures was reduced by animal defoliation ( $P<.10$ ). A similar effect occurred only in the bottom layer of bahia-aeschynomene pastures. The proportion of grass leaf in both layers of bahia-aeschynomene pastures appeared to be lower than that in similar layers of bahiagrass pastures (table 7) because of the presence of legume in bahia-aeschynomene pastures.

Forage CP and IVOMD were affected by interactions of grazing management, pasture type and canopy layer ( $P=.016$  and  $.079$ , respectively; table 8). In bahiagrass pastures at the beginning of

Table 8 Least squares means for the interaction of pasture type, grazing management (before (BRG) and after (ARG) rotational grazing, and continuous grazing (CG) and canopy layer on forage nutritive value (n=6)

Item <sup>a</sup>	Layer <sup>b</sup> (L)	Pasture (T) * Management (M)				Statistics <sup>c</sup>			
		Bahigrass		Bahia-aeschynomene		SEM		P	
		BRG	ARG	CG	CG	BRG	ARG	CG	CG
CP, %	2	8.9 <sup>d</sup>	7.6 <sup>e</sup>	7.0 <sup>e</sup>	13.6 <sup>d</sup>	9.5 <sup>e</sup>	9.5 <sup>e</sup>	9.5 <sup>e</sup>	.016
	1	7.6	7.2	6.5	8.6	7.5	8.0	0.38	.398
PDIFF		.010	.138	.144	.001	.019	.035		
IVOMD, %	2	53.5 <sup>d</sup>	46.4 <sup>e</sup>	42.7 <sup>e</sup>	50.0 <sup>d</sup>	44.3 <sup>e</sup>	42.7 <sup>e</sup>	1.34	.079
	1	50.6 <sup>d</sup>	49.4 <sup>d</sup>	43.2 <sup>e</sup>	46.7	43.0	43.1	1.80	.282
PDIFF		.042	.041	.634	.028	.207	.650		

<sup>a</sup> CP=crude protein; PDIFF=probability of the difference; IVOMD=in vitro organic matter digestion

<sup>b</sup> 1=bottom layer 10-20 cm above ground level; 2=grazing horizon over 20 cm above ground level

<sup>c</sup> SEM=standard error of mean; P=probability; Values for T\*M refer to the statistics for the analysis within layer; Values for T\*M\*L refer to the statistics for the interaction between pasture type, grazing management and canopy layer

def Means in a row within pasture type with different letters are different (P<.10)

rotational grazing, forage CP in the grazing horizon was higher than that in the bottom layer ( $P=.010$ ). No differences in forage CP between layers of bahiagrass pastures were observed, however, at the end of rotational grazing or under continuous grazing. In bahia-aeschynomene pastures, the grazing horizon always showed a higher forage CP than did the bottom layer ( $P<.04$ ). In the grazing horizon of bahiagrass pastures forage CP was higher before rotational grazing than under continuous grazing ( $P<.10$ ). No differences in CP, however, were found in the grazing horizon between after rotational grazing and continuous grazing. Forage CP in the grazing horizon of bahiagrass pastures was reduced by animal defoliation ( $P<.10$ ). No differences were found in forage CP in the bottom layer of bahiagrass pastures due to grazing management or animal defoliation.

In bahia-aeschynomene pastures, forage CP in the grazing horizon was lower under continuous grazing than before rotational grazing ( $P<.10$ ); table 8). No difference in forage CP was found, however, for grazing horizon between continuous grazing and after rotational grazing. In these pastures, like in bahiagrass pastures, the bottom layer did not differ in forage CP whether the pastures were continuously or rotationally grazed. Animal defoliation reduced forage CP in the grazing horizon of bahia-aeschynomene as was observed in bahiagrass pastures. These responses to grazing management indicate a benefit in terms of forage CP in the top of the canopy when bahiagrass or bahia-aeschynomene pastures are grazed rotationally. This offers the opportunity of a higher forage CP for animals at the beginning of the rotational grazing period. The benefit of overseeding aeschynomene

inbahiagrass pastures is also shown where forage CP of the grazing horizon is maintained high independent of grazing management. Of course, the levels of forage CP will depend on the proportion of legume in the canopy. The advantages of rotational grazing and overseeding of aescynomene in terms of forage CP might not be readily obvious when looking at the whole canopy.

Forage IVOMD in the grazing horizon was higher than that in the bottom layer of bahiagrass pastures before rotational grazing ( $P=.042$ ; table 8). After rotational grazing forage IVOMD in the bottom layer of bahiagrass pastures was higher than that in grazing horizon ( $P=.041$ ). Lower IVOMD in grazing horizon after grazing may be due to defoliation of the grazing horizon which did not occur in the bottom layer. Canopy layers in continuously-grazed bahiagrass pastures did not differ in forage IVOMD but IVOMD was lower than when rotationally-grazed.

In bahia-aescynomene pastures, the grazing horizon had higher forage IVOMD than did the bottom layer before rotational grazing ( $P=.028$ ; table 8). No differences in IVOMD were found between layers, however, either after rotational grazing or when pastures were grazed continuously. Forage IVOMD in the grazing horizon of bahia-aescynomene pastures before rotational grazing was higher than that when these pastures were grazed continuously ( $P<.10$ ). Animal defoliation during rotational grazing reduced forage IVOMD in the grazing horizon to levels similar to those found in the continuously-grazed bahia-aescynomene pastures ( $P<.10$ ). Forage IVOMD in the bottom layer of bahia-aescynomene pastures was not affected by grazing management or animal defoliation. Forage IVOMD appeared to be somewhat

lower in bahia-aeschynomene pastures compared to bahiagrass pastures, particularly in the bottom layer of rotationally-grazed pastures, probably because of the presence of less-digestible legume stem. The responses of forage IVOMD to grazing management indicate, again, a benefit of rotational grazing for bahia-aeschynomene and, particularly, bahiagrass pastures.

#### Cycle effects

There was an interaction between canopy layers and cycle on legume leaf percentage ( $P=.002$ ) and legume stem percentage ( $P=.004$ ) in bahia-aeschynomene pastures (table 9). In September and October legume leaf percentage in the grazing horizon was higher than that in the bottom layer ( $P=.001$ ). In November, however, no difference in legume leaf percentage was found between canopy layers. No difference in legume stem between layers was found in September. In October and November, however, the percentage of legume stem in the grazing horizon was higher than that in the bottom layer ( $P<.01$ ). The data illustrate stages of growth of the legume across the season. Early in the season the legume plants are young and small with a high leaf/stem ratio. As the plant matures, larger absolute amounts of leaf and stem are found in the pasture; however, the leaf/stem ratio declines.

Legume leaf percentage and stem percentage in both layers of the canopy changed with cycle ( $P<.10$ ; table 9). In the grazing horizon, legume leaf percentage was maximum in September and October, then declined in November. Legume stem percentage in the grazing horizon and legume leaf percentage and legume stem percentage in the bottom layer increased with maximum levels in October and then declined in November.

Table 9 Least squares means for the interaction of cycle and canopy layer on legume leaf and stem percentage in bahia-aeschynomene pastures (n=6), and on dead material percentage across all pastures (n=12)

Item <sup>a</sup>	Layer <sup>b</sup>	Cycle <sup>c</sup> (C)				SEM <sup>c</sup>		pd	
		2	3	4		C	C*Layer	C	C*Layer
Legume leaf, %	2	10.9 <sup>e</sup>	11.9 <sup>e</sup>	1.8 <sup>f</sup>		1.20	0.90	.002	.002
	1	1.8 <sup>f</sup>	3.4 <sup>e</sup>	0.4 <sup>g</sup>		0.44		.009	
PDIFF		.001	.001	.297					
Legume stem, %	2	9.5 <sup>g</sup>	31.4 <sup>e</sup>	19.1 <sup>f</sup>		2.38	1.74	.002	.004
	1	9.7 <sup>f</sup>	17.0 <sup>e</sup>	9.3 <sup>f</sup>		0.64		.001	
PDIFF		.939	.001	.002					
Dead material, %	2	16.3 <sup>g</sup>	21.1 <sup>f</sup>	38.8 <sup>e</sup>		1.63	1.47	.001	.035
	1	22.0 <sup>g</sup>	28.8 <sup>f</sup>	38.5 <sup>e</sup>		1.30		.001	
PDIFF		.001	.015	.870					

<sup>a</sup> PDIFF=probability of the difference

<sup>b</sup> 1-Bottom layer 10-20 cm above ground level; 2-grazing horizon over 20 cm above ground level

<sup>c</sup> Cycles correspond to September, October and November respectively

<sup>d</sup> SEM-standard error of mean; P-probability; Values for C refer to the statistics for the analysis within layer; Values for C\*Layer refer to the interaction between cycle and canopy layer

<sup>e,f,g</sup> Means in a row with different letters are different (P<.10)

The October increase is most evident for legume stem in the grazing horizon, and is similar to whole canopy legume percentage which reached maximum levels in October (table 4). Similar observations were made by Rusland et al. (1988). Legume stem increased by about 300% in the grazing horizon and by about 75% in the bottom layer from September to October. The decline of the legume in November was due to a decline of legume leaf percent in the grazing horizon of about 600% and to a decline of legume stem percent of 60% in the grazing horizon and of 80% in the bottom layer. The decline in legume in November is due to the reproductive stage of the plant. During this month the partition of photosynthate is probably directed towards the development of reproductive organs and seed production, and there is loss of leaves.

There was an interaction between canopy layers and cycle for dead material percentage across all pastures ( $P=.035$ ; table 9). Dead material was higher in the bottom layer than in the grazing horizon in September and October ( $P<.02$ ). No difference in this respect was found, however, in November. Accumulation of dead herbage at the end of the season illustrates the decline in the rate of growth of bahiagrass with the advance of the season and also the decrease in legume percentage in November.

There was an interaction between cycle, pasture type and canopy layer for weed percentage ( $P=.009$ ; table 10). In bahiagrass pastures there was no difference between layers in September but there was thereafter with an increasing difference up to November ( $P<.04$ ). Weed percentage increased in the grazing horizon ( $P<.10$ ) with no change in the bottom layer. The grazing horizon had higher percentage of weeds

Table 10 Least squares means for the interaction of cycle, pasture type, and canopy layer on weed percentage (n=12)

Pasture type <sup>a</sup> (T)	Layer <sup>b</sup> (L)	Cycle <sup>c</sup> (C)			SEM <sup>d</sup>			P <sup>e</sup>	
		2	3	4	C*T	C*T*L	C*T*L	C*T	C*T*L
Bahia-grass	2	8.9 <sup>h</sup>	18.3 <sup>g</sup>	25.2 <sup>f</sup>	2.38	2.06	.001	.009	
	1	9.4	12.1	13.0	1.68			.538	
PDIFF		.846	.036	.001					
Bahia-aeschy.	2	25.1	20.7	18.0					
	1	15.9	16.6	15.6					
PDIFF		.014	.224	.473					

<sup>a</sup> PDIFF=probability of the difference; Bahia-aeschy.=bahia-aeschynomene pastures

<sup>b</sup> 1=bottom layer 10-20 cm above ground level; 2=grazing horizon over 20 cm above ground level

<sup>c</sup> Cycles correspond to September, October and November respectively

<sup>d</sup> SEM=standard error of mean; Values for C\*T refer to the statistics for the analysis within layer; Values for C\*T\*L refer to the interaction between cycle, pasture type, and canopy layer

<sup>e</sup> P=probability value

<sup>fgh</sup> Means in a row with different letters are different (P<.10)



than did the bottom layer in bahia-aeschynomene pastures in September ( $P=.014$ ). No differences in this respect were found thereafter.

#### Diet Botanical Composition and Nutritive Value

Analyses of variance for diet data are in tables 35 through 37, appendix.

#### Pasture type main effects

A higher percentage of weeds was found in the diet of animals grazing bahia-aeschynomene than in those grazing bahiagrass ( $P=.012$ ; table 11). The weed percentages in the grazing horizon of bahia-aeschynomene pastures and bahiagrass pastures were 21.3 and 17.5%, respectively ( $P=.144$ ). The data suggest that animals selected against weeds.

Dead material percentage was higher in the diet of animals grazing bahiagrass pastures ( $P=.054$ ; table 11). The canopy data did not indicate a higher dead material percentage in bahiagrass as compared to bahia-aeschynomene pastures ( $P=.215$ ) and the means in the grazing horizon were 24.5 and 26.3%, respectively. This suggests that animals did not discriminate against dead material in bahiagrass pastures as well as they did in bahia-aeschynomene pastures. Most dead material in bahiagrass or bahia-aeschynomene pastures was of bahiagrass origin. So, dead material is well mixed with green grass making it more difficult for the animal to select only for green material.

Animals grazing bahia-aeschynomene pasture consumed a diet that was greater in CP percentage than did those grazing bahiagrass ( $P=.003$ ; table 11). The difference in diet CP was likely due to the presence of legume in the bahia-aeschynomene pastures. The calculated forage CP

Table 11 Least squares means for the effect of pasture type (bahiagrass (B) and bahia-aeschynomene (BA)) on botanical composition and nutritive value of the diet ingested by animals (n=24)

Item <sup>a</sup>	Pasture		Statistics <sup>b</sup>	
	B	BA	SEM	P
Weeds, %	7.9	13.0	1.01	.012
Dead material, %	12.2	9.2	0.91	.054
CP, %	9.5	13.9	0.61	.003
IVOMD, %	56.6	52.3	0.61	.003

<sup>a</sup> CP=crude protein; IVOMD=in vitro organic matter digestion

<sup>b</sup> SEM=standard error of mean, the highest value is shown; P=probability value

average in the whole canopy (table 4) was 7.5 and 8.6% for bahiagrass and bahia-aeschynomene pastures, respectively. Animals were able to select a diet higher in CP than that on offer in the whole canopy (table 4) and in the grazing horizon (table 8). The differences in forage CP between pastures, however, were reflected in differences in diet CP.

The IVOMD of the diet consumed by animals grazing bahiagrass was higher than that consumed by animals grazing bahia-aeschynomene pastures ( $P=.003$ ; table 11). The difference in diet IVOMD was similar to that observed for whole canopy forage IVOMD (table 2). According to canopy layer data (table 8) the difference in forage IVOMD between pasture types was in the bottom layer rather than in the grazing horizon. The difference in the bottom layer, however, was not consistent. The presence of legume stem in bahia-aeschynomene pastures, particularly in the bottom layer, might be related to any forage IVOMD difference between pasture types.

It is important to note that animals were able to consume diets with higher CP and IVOMD percentage than those of the whole canopy (table 2 and 4) and canopy layers (table 8). These data indicate animal selection of the more nutritious botanical components in the pasture.

#### Grazing management main effects

Animals on continuously-grazed pastures consumed a diet greater in weed percentage than did those on rotationally-grazed pastures ( $P=.065$ ; table 12). The difference appears to be similar to that observed in the whole canopy where continuously-grazed pastures had higher percentages of other materials than did rotationally-grazed pastures

Table 12 Least squares means for the effect of grazing management (before (BRG) and after (ARG) rotational grazing, and continuous grazing (CG)) on diet botanical composition and nutritive value (n=16)

Item <sup>a</sup>	Management			Statistics <sup>b</sup>	
	BRG	ARG	CG	SEM	P
Weeds, %	8.6 <sup>d</sup>	9.2 <sup>d</sup>	13.4 <sup>c</sup>	1.24	.065
Dead material, %	5.6 <sup>d</sup>	14.3 <sup>c</sup>	12.3 <sup>c</sup>	1.11	.003
CP, %	14.2 <sup>c</sup>	9.6 <sup>d</sup>	11.3 <sup>d</sup>	0.75	.015
IVOMD, %	55.6 <sup>c</sup>	55.1 <sup>c</sup>	52.4 <sup>d</sup>	0.75	.048

<sup>a</sup> CP=crude protein; IVOMD=in vitro organic matter digestion

<sup>b</sup> SEM=standard error of mean; P=probability value

<sup>cd</sup> Means in a row with different letter are different (P<.10)

(table 4). The layer data indicated, however, that the difference in other percentage was related to differences in dead material rather than weeds (table 6). An observation from the field was that animals on continuously-grazed pastures grazed mostly from new regrowth in short canopy areas that had been grazed before. In these shorter canopy areas the percentage of weeds appeared to be relatively high as compared to rejected spots of more mature forage in the pasture. Grazing short spots might be the reason for the higher percentage of weeds in the diet of animals under continuous grazing. The percentage of weeds in the diet was not affected by animal defoliation during rotational grazing.

The percentage of dead material in the diet of animals grazing pastures under continuous management was higher than that when animals sampled rotationally-grazed pastures at the start of the grazing period ( $P < .10$ ; table 12). No difference in diet dead material percentage was found between continuous grazing and after rotational grazing samples because dead material percentage increased as an effect of animal defoliation during the grazing period ( $P < .10$ ). Diet changes were similar to the response of dead material to animal defoliation observed in the canopy data (table 6). In the whole canopy, other percentage was similar between after rotational grazing and continuous grazing in bahia-aeschynomene pastures but higher for continuous grazing in bahiagrass pastures (table 4). Canopy layers showed higher dead material percentage in continuously-grazed than in rotationally-grazed pastures (table 6). In continuously-grazed pastures, the percentage of dead material appeared to be much higher in rejected spots of mature grass than in the short canopy areas where animals grazed the most.

Perhaps, animals grazed from areas that contained lower dead material percentages than shown for the pasture average. In addition to animal selection against dead material, grazing from pasture areas having low dead percentage would explain why the effect of grazing management on dead material percentage in pastures is not reflected in the diet of the animals. An important observation is that the percentages of dead material and weeds in the diet of the animals were lower than those found in the pasture (tables 6 and 10), indicating animal discrimination against the lowest nutritional components in the pasture.

Dietary CP concentration was lower for continuous grazing than before rotational grazing ( $P < .10$ ; table 12). No difference in diet CP was found between continuous grazing and after rotational grazing. Animal defoliation in rotationally-grazed pastures resulted in reduced dietary CP concentration ( $P < .10$ ). Changes in diet CP agreed with those observed in the grazing horizon of bahiagrass and bahia-aeschynomene pastures (table 8). Higher CP levels in the diet as compared to the whole canopy (table 4) and even to the grazing horizon indicate animal selectivity.

Diet IVOMD of animals was higher when grazing pastures under rotational management than when grazing pastures under continuous management ( $P < .10$ ; table 12). A similar response was observed for whole canopy forage IVOMD (table 3) and grazing horizon forage IVOMD (table 8). Animal defoliation during rotational grazing did not affect diet IVOMD. In the whole canopy and canopy layers, however, forage IVOMD was reduced due to animal defoliation. These results and the higher IVOMD levels in the diet as compared to the whole canopy and canopy layers

indicate animal selectivity. The results of diet and pasture canopy CP and IVOMD suggest that animals selected for those botanical components in the pasture of highest nutritive value.

#### Pasture type-grazing management interactions

There was an interaction between pasture type and grazing management on diet grass leaf percentage ( $P=.001$ ; table 13). A lower percentage of grass leaf was found in the diet of animals under continuous grazing than under rotational grazing of bahiagrass pastures ( $P<.10$ ; table 13). For bahia-aeschynomene pastures diet grass leaf percentage under continuous grazing was higher than that before rotational grazing but similar to that after rotational grazing. Animal defoliation during rotational grazing reduced diet grass leaf percentage in bahiagrass pastures. In bahia-aeschynomene pastures defoliation increased diet grass leaf percentage ( $P<.10$ ).

The effects of grazing management and animal defoliation on grass leaf percentage in the diet of animals grazing bahiagrass pastures were similar to those for grass percentage in the whole canopy (table 4) and within the canopy layers (table 7). The magnitude of the differences, however, was smaller in the diet. Animals grazing bahiagrass rotationally consumed a diet with a grass leaf percentage similar to that in the whole canopy. Under continuous grazing, however, animals consumed a diet with 40% more grass leaf than that in the canopy. Comparing the composition of the diet with the composition of the grazing horizon, animals consumed 18, 37, and 78% more grass leaf than that in the grazing horizon of bahiagrass pastures at the beginning and end of rotational grazing and under continuous grazing,

Table 13 Least squares means for the interaction of pasture type (bahia grass (B) and bahia-aeschynomene (BA)), and grazing management (before (BRG) and after (ARG) rotational grazing, and continuous grazing (CG)) on diet grass leaf and stem percentage; and grazing management effect on diet legume leaf and stem in bahia-aeschynomene pastures (n=8)

Item	B			BA			Statistics <sup>a</sup>	
	BRG	ARG	CG	BRG	ARG	CG	SEM	P
Grass leaf, %	82.4 <sup>b</sup>	75.4 <sup>c</sup>	72.2 <sup>d</sup>	37.3 <sup>c</sup>	44.4 <sup>b</sup>	43.5 <sup>b</sup>	1.20	.001
Grass stem, %	2.9	3.1	3.6	0.8 <sup>d</sup>	4.8 <sup>b</sup>	3.0 <sup>c</sup>	0.70	.099
Legume leaf, %				27.6 <sup>b</sup>	5.4 <sup>c</sup>	10.5 <sup>c</sup>	3.22	.034
Legume stem, %				20.7	19.9	15.8	1.98	.312

<sup>a</sup> SEM=standard error of mean; P=probability value

<sup>bcd</sup> Means in a row within pasture type with different letters are different (P<.10)



respectively. These results indicate animal selection for grass leaf in bahiagrass pastures. Animal selection of grass leaf became more intense as the percentage of grass leaf was reduced in the canopy, particularly in the grazing horizon.

In continuously-grazed bahia-aeschynomene pastures, animals consumed a diet that was greater in grass leaf percentage compared to the diet consumed by cattle at the beginning of the rotational grazing period ( $P < .10$ ); table 13). Grass leaf percentage in the diet of animals increased as an effect of animal defoliation ( $P < .10$ ). The response of grass leaf percentage to grazing management in bahia-aeschynomene pastures is related to the presence of the legume in the canopy and its defoliation by animals. Diet grass leaf percentage was somewhat similar to grass percentage in the whole canopy (table 4) and grass leaf percentage in bottom layer of bahia-aeschynomene pastures (table 7). Animals consumed a diet having 63, 64, and 90% more grass leaf than that in the grazing horizon (table 8) at the beginning and end of rotational grazing and during continuous grazing, respectively, in bahia-aeschynomene pastures. These results indicate that relative to the whole canopy animals grazing bahia-aeschynomene pastures did not appear to select grass leaf. However, animals strongly selected for grass leaf when the diet was compared to the grazing horizon, particularly under continuous grazing. Brown et al. (1987) reported no indication of selection of grass leaf relative to the upper layer of stargrass-aeschynomene pastures.

Grass stem percentage in the diet was affected by grazing management in bahia-aeschynomene but not in bahiagrass pastures ( $P = .099$ ;

table 13). The dietary levels of this botanical component were low, as the percentage of grass stem was also low in the canopy, and probably of no biological importance.

Animals grazing bahia-aeschynomene pastures at the beginning of rotational grazing had a greater percentage of legume leaf in the diet than did animals under continuous grazing ( $P<.10$ ; table 13). Legume leaf percentage in the diet was reduced by animal defoliation during rotational grazing to levels similar to those found under continuous grazing ( $P<.10$ ). Responses of diet legume leaf percentage to grazing management and animal defoliation were similar to those observed for legume leaf percentage in the whole canopy (table 4) and in the grazing horizon (table 6). Diet legume leaf percentage was 86, 42, and 75% greater than that in the grazing horizon for animals grazing at the beginning and end of rotational grazing and under continuous grazing, respectively. These results indicate that animals selected for legume leaf. Brown et al. (1987) reported higher levels of dietary legume leaf than those in the upper layer at the beginning of the grazing period in stargrass-aeschynomene pastures.

Grazing management and animal defoliation did not affect diet legume stem percentage (table 13). Legume stem percentage before rotational grazing was 27% lower in the diet than in the grazing horizon of bahia-aeschynomene pastures (table 6). After rotational grazing animals consumed similar percentages of legume stem as those found in the grazing horizon. Animals under continuous grazing consumed 32% more legume stem than that in the grazing horizon.

As a total, animals consumed 48.3, 25.3, and 26.3% legume at the beginning and end of rotational grazing and under continuous grazing, respectively. Total legume consumed was 118, 113, and 150% greater than the percentages of legume present in the whole canopy of these pastures, respectively. Relative to the grazing horizon, where most of the legume leaf and fine stem were located, under rotational grazing the percentage of total dietary legume was 10% greater. Moore and Sollenberger (1986) reported diet legume percentages equal to or higher than that in the upper layer of limpgrass-aeschynomene pastures. Under continuous grazing, however, animals consumed a diet containing 46% more legume than was present in the grazing horizon.

The percentage of grass leaf in diet of animals grazing bahiagrass pastures indicates that animals selected for this botanical component, particularly in relation to the grazing horizon. Animals were not forced to select as much under rotational grazing management as they were under continuous grazing. The proportion of green material in the canopy was probably the driving force to animal selectivity. In rotationally-grazed bahia-aeschynomene pastures animals did not have to select much for legume as a total because most of the legume available in the pasture was at the top of the canopy. In continuously-grazed bahia-aeschynomene pastures animals intensified legume selection because the legume not only was palatable to them but because in these pastures animals were forced to select for green herbage. In all cases animals selected for legume leaf as compared to legume stem. Animals selected for legume stem when they were forced to do so by the reduction of green material, i.e., under continuous grazing. In this case, however, the

selection for legume leaf was twice as much as for legume stem. The presence of legume leaf at the top of the canopy, its palatability and selection by the animal did not influence negatively the consumption of grass leaf. Grass leaf was better distributed across the canopy than was the legume. The greater dietary grass leaf percentage relative to that in the grazing horizon indicated that animals consumed the legume in the top of the canopy and went down the canopy to consume the grass leaf, also. So, in both pasture types, animals selected for green material, namely, legume leaf and/or grass leaf. Animals avoided consuming dead material, weeds and probably woody legume stem. Because the presence of these botanical components, particularly weeds and dead material, were in lower percentage when pastures were grazed rotationally, it was much easier to harvest desirable green material early in rotational grazing than under continuous grazing.

#### Cycle effects

Diet legume leaf percentage changed with cycle ( $P < .001$ ; table 14). The response was similar to the response of legume percentage to cycle in the whole pasture canopy (table 5). Even the magnitude of the levels of legume leaf percentage in the diet were somewhat similar to the whole canopy legume percentage. The legume leaf percentage in the diet was higher than the legume leaf percentage in the grazing horizon by about 63% and 86% in September and October, respectively (table 9). Legume leaf percentage in the grazing horizon (table 9) showed similar levels in September and October, as did the diet (table 14). In November, legume leaf percentage in the grazing horizon (table 9) and

Table 14 Least squares means for the effect of cycle on diet legume leaf and stem percentage in bahia-aeschynomene pastures (n=12)

Item	Cycle <sup>a</sup>				Statistics <sup>b</sup>	
	1	2	3	4	SEM	P
Legume leaf, %	14.3 <sup>d</sup>	17.8 <sup>cd</sup>	22.1 <sup>c</sup>	3.8 <sup>e</sup>	1.99	.001
Legume stem, %	7.9 <sup>e</sup>	14.4 <sup>d</sup>	39.1 <sup>c</sup>	13.8 <sup>d</sup>	2.03	.001

<sup>a</sup> Cycles correspond to August, September, October and November, respectively

<sup>b</sup> SEM=standard error of mean; P=probability value

<sup>cde</sup> Means in a row with different letters are different (P<.10)

legume percentage in the whole canopy (table 5) dropped and so did the legume leaf percentage in the diet of the animals. The low availability of legume, particularly legume leaf, in November, was related to the reproductive stage of the legume plant as mentioned earlier.

Legume stem percentage in the diet of animals showed response to cycle, also ( $P < .001$ ; table 14). Both legume leaf percentage and legume stem percentage in the diet peaked in October as did legume percentage in the whole canopy (table 5). Relative to the legume stem percent in the grazing horizon (table 9), the diet showed a similar peak in October; however, this was still 25% higher than that in the grazing horizon.

The whole pasture canopy and canopy layers showed that the response of the legume to season was more a response of the legume stem than of the legume leaf. A similar response occurred in the diet of the animals; however, animal selectivity was an important factor in the higher levels of legume, particularly of legume leaf, in the diet.

There was an interaction between pasture type and cycle for dietary CP concentration ( $P = .001$ ; table 15). Crude protein in the diet of animals grazing bahiagrass was very similar across the season. Animals grazing bahia-aeschynomene pastures consumed a diet of increasing CP concentration as the season progressed until November when diet CP decreased ( $P < .10$ ). Animals on bahia-aeschynomene pastures had much higher levels of CP in the diet than did those in bahiagrass pastures ( $P < .001$ ), with the difference increasing from August to October and then declining in November. The response of CP in the diet of animals grazing bahia-aeschynomene pastures follows the response of legume

Table 15 Least squares means for the interaction of cycle and pasture type on diet crude protein concentration (n=6)

Pasture type <sup>a</sup>	Cycle <sup>b</sup>				Statistics <sup>c</sup>	
	1	2	3	4	SEM	P
Bahiagrass	9.0 <sup>e</sup>	9.7 <sup>de</sup>	9.5 <sup>de</sup>	10.0 <sup>d</sup>	0.37	.001
Bahia-aeschy.	12.0 <sup>e</sup>	13.4 <sup>e</sup>	17.6 <sup>d</sup>	12.5 <sup>e</sup>		
PDIFF	.001	.001	.001			

<sup>a</sup> Bahia-aeschy=bahia-aeschynomene pastures; PDIFF=probability of the difference

<sup>b</sup> Cycles correspond to August, September, October and November, respectively

<sup>c</sup> SEM=standard error of mean; P=probability value

<sup>de</sup> Means in a row with different letters are different (P<.10)

percentage in the diet (table 14) and in the whole canopy (table 5) from August to November, and the response of legume stem percentage in the canopy layers from September to November (table 9). The levels of CP in the diet of animals grazing bahiagrass or bahia-aeschynomene pastures were higher than the levels of forage CP found in the whole canopy (table 4) or canopy layers. Animal selection of more nutritious botanical components is clear from these data, particularly in bahiagrass pastures where selection of botanical components with high CP concentrations is not as obvious as in bahia-aeschynomene pastures.

#### Animal Ingestive Behavior

Analyses of variance for ingestive behavior data are in table 38, appendix.

#### Pasture type main effects

Animals grazing bahiagrass pastures had a larger bite weight than did animals on bahia-aeschynomene pastures ( $P=.012$ ; table 16). Intake per minute, however, was similar between pasture types because animals on bahia-aeschynomene pastures had a higher number of bites per minute than did those on bahiagrass pastures ( $P=.014$ ). The faster biting rate compensated for the smaller bite weight of animals grazing bahia-aeschynomene pastures. Brown et al. (1987) reported that cattle grazing stargrass pastures had a slower bite rate but larger bite weight compared to cattle grazing stargrass-aeschynomene pastures. The combination of bite rate and bite weight in the mentioned study, however, resulted in greater intake per minute for animals grazing the grass-alone pastures. The number of bites per 100 jaw movements (B100JM) were not different between animals grazing bahiagrass or



Table 16 Least squares means for the effect of pasture type (bahiagrass (B) and bahia-aeschynomene (BA) on animal ingestive behavior (n=24)

Item <sup>a</sup>	Pasture		Statistics <sup>b</sup>	
	B	BA	SEM	P
Bites/min	40.7	44.3	0.74	.014
Bites/100 JM	54.6	57.5	1.49	.223
Bite weight, g OM	0.56	0.50	0.012	.012
Intake/min, g OM	23.0	22.6	0.56	.658

<sup>a</sup> JM-jaw movements; OM-organic matter

<sup>b</sup> SEM=standard error of mean; P-probability value

bahia-aeschynomene pastures. This means that animals did as much manipulation in one type of pasture as in the other in order to harvest the forage. In stargrass-aeschynomene pastures (Brown et al., 1987), cattle tended to manipulate forage less compared to grass-alone pastures.

#### Grazing management main effects

The B100JM of animals under continuous grazing was similar to that before rotational grazing but higher than that after rotational grazing ( $P < .10$ ; table 17). The B100JM were reduced as an effect of animal defoliation during the rotational grazing period. Brown et al. (1987) reported reduction in B100JM at the end of the grazing period in stargrass-aeschynomene and stargrass pastures.

Bites per 100 jaw movements is a measurement that can indicate when an animal finds it difficult to harvest the most desirable botanical components in the pasture. This is because the animal might need to make more manipulations with tongue and mouth in order to graze in a particular canopy. The more the manipulations, the lower the number of actual bites per 100 jaw movements. There was no clear indication in the canopy data, however, of the reason why animals on rotationally-grazed pastures had more problems to harvest forage at the end of the grazing period than did animals on continuously-grazed pastures. None of the canopy characteristics were affected by grazing management and animal defoliation in the way B100JM was affected. An observation in the field was that the fistulated animals appeared to be reluctant to graze the pastures at the end of the rotational grazing period. They did more walking and smelling of the forage than they normally did in

Table 17 Least squares means for the effect of grazing management (before (BRG) and after (ARG) rotational grazing, and continuous grazing (CG)) on animal ingestive behavior (n=16)

Item <sup>a</sup>	Management			Statistics <sup>b</sup>	
	BRG	ARG	CG	SEM	P
Bites/min	46.9 <sup>c</sup>	36.9 <sup>e</sup>	43.8 <sup>d</sup>	0.91	.001
Bites/100 JM	60.7 <sup>c</sup>	49.0 <sup>d</sup>	58.4 <sup>c</sup>	1.82	.009
Bite weight, g OM	0.67 <sup>c</sup>	0.48 <sup>d</sup>	0.45 <sup>d</sup>	0.015	.001
Intake/min, g OM	30.7 <sup>c</sup>	17.6 <sup>e</sup>	20.0 <sup>d</sup>	0.68	.001

<sup>a</sup> JM=Jaw movements; OM=organic matter

<sup>b</sup> SEM=standard error of mean; P=probability value

<sup>cde</sup> Means in a row with different letters are different (P<.10)

the other treatments. They also chewed and kept their heads up for longer periods. Apparently the fresh trailing and soiling of the pastures had a great impact on grazing behavior of the animals. Then, the decreased B100JM in animals after rotational grazing might be due more to a reluctance to graze than to an actual difficulty in harvesting forage in the pasture. Wade and Le Du (1981) reported that the presence of sheep excreta had a greater effect on herbage intake of calves than did the spatial distribution of the swards.

Animals obtained a larger bite weight before rotational grazing than under continuous grazing ( $P < .10$ ; table 17). No difference in bite weight was found between the end of rotational grazing and continuous grazing because bite weight was reduced as an effect of animal defoliation during rotational grazing. The effect of grazing management and animal defoliation on bite weight is similar to that on whole canopy herbage mass and canopy height (table 3) discussed earlier. Changes in bite weight do not appear to be related to grass leaf in the whole canopy of either pasture, but they might follow the effect observed on whole canopy legume percent and forage CP in bahia-aeschynomene pastures (table 4). The response of bite weight to grazing management and animal defoliation was also similar to that for forage CP and IVOMD in the grazing horizon of both type of pastures (table 8). Decreased bite weight due to reduction in herbage mass or leaf material has been reported by others (Stobbs, 1973a; Hendricksen and Minson, 1980; Forbes and Hodgson, 1985; Brown et al., 1987).

Intake per minute was 50% higher before rotational grazing than under continuous grazing ( $P < .10$ ; table 17). Animal defoliation,

however, depressed intake per minute by about 43% to levels even lower than those found under continuous grazing. This decreased intake per minute was due to decreases in both bite weight and bites per minute at the end of the rotational grazing period (table 17). Bite weight under continuous grazing was similar to that after rotational grazing but biting rate was higher under continuous grazing ( $P < .10$ ; table 17) resulting in a higher intake per minute.

#### Pasture type-grazing management interaction

In bahiagrass pastures the number of bites per minute before rotational grazing was similar to that under continuous grazing (table 18). In bahia-aeschynomene pastures, however, the number of bites per minute before rotational grazing was higher than that under continuous grazing ( $P < .10$ ). In both pasture types, bites per minute were reduced as an effect of animal defoliation during rotational grazing ( $P < .10$ ). The magnitude of the reduction was similar in both cases, about 21%. Relative to the continuous grazing system, however, animals on bahiagrass pastures after rotational grazing had a biting rate 23% lower. No difference in this respect was found in animals grazing bahia-aeschynomene pastures. Others have reported increased bites per minute with reduction in herbage mass due to defoliation (Allden, 1962; Chacon and Stobbs, 1976; Scarnecchia et al., 1985). Chacon and Stobbs (1976) reported, however, that further decrease in herbage mass at later stages of defoliation reduced not only bite weight but also bites per minute.

These effects of grazing management and animal defoliation on biting rate of animals grazing bahia-aeschynomene pastures are similar

Table 18 Least squares means for the interaction of pasture type and grazing management (before (BRG) and after (ARG) rotational grazing, and continuous grazing (CG)) on bites per minute (n=8)

Pasture type <sup>a</sup>	Management			Statistics <sup>b</sup>	
	BRG	ARG	CG	SEM	P
Bahiagrass	43.4 <sup>c</sup>	34.2 <sup>d</sup>	44.6 <sup>c</sup>	1.28	.033
Bahia-aeschy.	50.5 <sup>c</sup>	39.4 <sup>d</sup>	43.0 <sup>d</sup>		
PDIFF	.008	.027	.422		

<sup>a</sup> Bahia-aeschy-bahia-aeschynomene pastures; PDIFF=probability of the difference

<sup>b</sup> SEM=standard error of mean; P=probability value

<sup>cd</sup> Means in a row with different letters are different (P<.10)

to the effects on whole canopy legume percentage (table 4) and grazing horizon legume leaf percentage (table 6) described earlier. In bahiagrass pastures, however, the responses of biting rate are not matched by any other response observed in the pasture canopy due to grazing management and animal defoliation. Early in this discussion, the possibility was mentioned that animal trailing and forage soiling might affect ingestive behavior of the animals at the end of a rotational grazing period. The biting rate data suggest that such an effect might be more likely in bahiagrass pastures than in bahia-aeschynomene pastures. Apparently, the presence of legume at the end of rotational grazing periods overrides the negative effect of trailing and soiling on grazing behavior of animals observed in bahiagrass pastures. Bites per minute in rotationally-grazed pastures were greater in bahia-aeschynomene than in bahiagrass pastures ( $P < .03$ ). When these two pasture types were grazed continuously, however, bites per minute were similar. Brown et al. (1987) reported greater bite rate in stargrass-aeschynomene than in stargrass pastures, and a reduction of bite rate as the pastures were defoliated. Moore and Sollenberger (1986) found more legume in the diet of animals when ingestive behavior involved increased manipulative activity in limpograss-aeschynomene pastures. In the present experiment legume percentage was higher when bites per minute were higher, i.e., when there was less manipulative activity.

Pasture Canopy Characteristics and Animal Ingestive  
Behavior Relationships

Bahiagrass Pastures

Animal ingestive behavior was affected by only a few characteristics of the whole canopy in bahiagrass pastures (table 19). Bite weight and intake per minute were positively correlated with canopy height. Biting rate was not related to any canopy characteristic in bahiagrass pastures. So, as canopy height decreased, bite weight decreased and so did intake per minute. Further, animals were not able to compensate for smaller bite weight by increasing the number of bites per minute. Chacon and Stobbs (1976) have shown bites per minute as a compensatory mechanism for decreasing bite weight. In face of a decreasing bite weight animals may increase their rate of biting to maintain constant intake. Characteristics of the canopy may be reached, however, when biting rate cannot increase. Under these conditions of small bite weight and limiting biting rate, intake is reduced, as was probably the situation in bahiagrass pastures in the present experiment. The stubble height allowed in these pastures was probably not responsible for the low bite rate because height of the canopy was similar after rotational grazing and under continuous grazing. Bites per minute, however, were greater under continuous grazing. Therefore, something other than canopy characteristics per se affected bites per minute at the end of rotational grazing. Grass percentage in the whole canopy tended to be negatively related to B100JM (table 19). This relationship means that animals tended to make more manipulative activities when grass percentage was higher.



Table 19 Simple correlations  
between whole canopy  
characteristics and  
animal ingestive behavior  
on bahiagrass pastures  
(n=12)

Item <sup>a</sup>	Height		Grass %	
	r <sup>b</sup>	p <sup>c</sup>	r	P
B100JM			-.57	.051
BW	.56	.057		
IPM	.63	.027		

<sup>a</sup> B100JM=bites per 100 jaw movements;

BW=bite weight; IPM=intake per minute

<sup>b</sup> r=correlation coefficient

<sup>c</sup> P=probability value

Bite weight was positively correlated with herbage mass in the grazing horizon ( $r=.62$ ,  $P=.042$ ;  $n=12$ ). No other correlation between bite weight and canopy layer characteristics was present. The relation of bite weight to herbage mass in the top of the canopy and to canopy height strongly suggests a larger bite weight in the top canopy. So, a reduction in herbage mass in the top layer and a reduction in canopy height resulted in a reduction of bite weight.

#### Bahia-aeschynomene Pastures

Bites per minute were positively correlated with herbage mass, canopy height, legume percentage and forage CP in the whole canopy (table 20). Jamieson and Hodgson (1979) reported increased bites per minute as green herbage mass was progressively reduced. Scarnecchia et al. (1985) reported positive correlations between bites per minute and plant height in crested wheatgrass pastures. Moore and Sollenberger (1986) reported a tendency for increased bites per minute as legume percentage was reduced in the canopy of limpograss-aeschynomene pastures. In the present study, whole canopy forage CP percentage and herbage mass showed the highest correlation with bites per minute. Legume percentage ( $n=12$ ) was highly and positively correlated with herbage mass ( $r=.91$ ,  $P=.001$ ) and forage CP ( $r=.88$ ,  $P=.001$ ). In bahiagrass pastures, however, no canopy characteristic was correlated with bites per minute. The high legume percentage is associated, then, with the higher biting rate observed for animals grazing bahia-aeschynomene compared to bahiagrass pastures before rotational grazing (table 18).

Table 20 Simple correlations between whole canopy characteristics and animal ingestive behavior for bahia-aeschynomene pastures (n=12; r=correlation coefficient; P=probability value)

Item <sup>a</sup>	HM <sup>b</sup>		Height		Legume %		Other %		CP <sup>c</sup> %	
	r	P	r	P	r	P	r	P	r	P
BPM	.82	.001	.78	.001	.68	.015			.84	.001
JPM			.62	.003			-.61	.036		
B100JM	.65	.021								
BW			.91	.001			-.70	.011		
IPM	.71	.009	.92	.001	.63	.027			.79	.002

<sup>a</sup> BPM=bites per minute; JPM=jaw movements per minute; B100JM=bites per 100 jaw movements; BW=bite weight; IPM=intake per minute

<sup>b</sup> HM=herbage mass

<sup>c</sup> CP=crude protein

Jaw movements per minute were positively correlated with canopy height and negatively correlated with other percentage in the whole canopy of bahia-aeschynomene pastures (table 20). As canopy height was reduced, legume leaf disappeared from the canopy and other herbage increased, and then jaw movement rate also decreased. In bahiagrass pastures, jaw movement rate was not related to any pasture characteristic. Moore and Sollenberger (1986) found no canopy characteristic in limpograss-aeschynomene pastures related to jaw movements.

Bites per 100 jaw movements were positively correlated with herbage mass (table 20). As the pasture was defoliated animals made more manipulations before biting. Animals found very contrasting canopy characteristics as they defoliated bahia-aeschynomene pastures. They went from grazing a canopy with a lot of legume leaf at the beginning of rotational grazing to a canopy with a lot of grass and legume stem at the end of rotational grazing and under continuous grazing. In bahiagrass pastures the canopy was not as contrasting as it was in bahia-aeschynomene pastures so changes in manipulative activity did not occur.

Bite weight was positively correlated with canopy height and negatively correlated to other percentage in whole canopy of bahia-aeschynomene pastures (table 20). Canopy height ( $n=12$ ) was positively correlated with forage CP ( $r=.82$ ,  $P=.001$ ) and legume percentage ( $r=.75$ ;  $P=.005$ ). The correlation between canopy height and forage CP was particularly high because of legume leaf in the top of the canopy. As

the canopy was defoliated, legume leaf, the major botanical component in the top canopy, was reduced and so was pasture herbage mass, legume percent, forage CP, and bite weight. This relationship can be seen simply as a reduction in the bite weight due to a reduction in legume leaf in the canopy. When this happened animals reduced biting rate and increased manipulations to obtain the remaining legume leaf in the canopy or to obtain grass, the new major component in the canopy after the defoliation of the legume.

Intake per minute was positively correlated with the same pasture characteristics as was biting rate (table 20). The highest magnitude correlations were with canopy height and forage CP indicating the influence of legume leaf on animal intake.

Herbage mass in both layers of bahia-aeschynomene pastures was positively correlated with bites per minute, particularly herbage mass in the bottom layer (table 21). Herbage mass in the bottom layer was positively correlated with B100JM. These correlations with herbage mass in the bottom layer suggest that as the herbage mass was reduced and dead material and weeds increased animals increased manipulative activity to select for the green leaf and reduced the rate of biting.

The influence of legume leaf percentage on animal ingestive behavior was confirmed in the grazing horizon and bottom layer of bahia-aeschynomene pastures (table 21). The correlations were positive and particularly high between legume leaf percentage in the grazing horizon and bite weight and intake per minute. Moore and Sollenberger (1986) did not find any effect of legume percentage in the upper layer of limpgrass-aeschynomene pastures on bite weight. Legume leaf percentage

Table 21 Simple correlations between canopy layer characteristics and animal ingestive behavior on bahia-aeschynomene pastures (n=12; r=correlation coefficient; P=probability value)

Item <sup>a</sup>	L <sup>b</sup>	HM <sup>c</sup>		LL <sup>d</sup> %		Dead %		Weeds %	
		r	P	r	P	r	P	r	P
BPM	2	.55	.081	.63	.036			-.53	.097
	1	.73	.007	.55	.063			-.60	.040
B100JM	2								
	1	.76	.004						
BW	2			.88	.001	-.71	.015		
	1			.59	.043				
IPM	2			.85	.001	-.65	.032		
	1			.59	.042				

<sup>a</sup> BPM=bites per minute; B100JM=bites per 100 jaw movements;  
BW=bite weight; IPM=intake per minute

<sup>b</sup> L=layer (2-grazing horizon, over 20 cm above ground level;  
1=bottom layer, 10-20 cm above ground level)

<sup>c</sup> HM=herbage mass

<sup>d</sup> LL=legume leaf

in both layers was also positively correlated with bites per minute. These correlations confirm the positive influence of legume leaf on biting rate observed in the ingestive behavior data discussed earlier.

Influences of dead material and weeds on ingestive behavior were also observed. Dead material in the grazing horizon was negatively correlated with bite weight and intake per minute (table 21). As with the canopy data (table 6), changes in dead material due to defoliation might occur faster in the grazing horizon than in the bottom layer and explain why there are correlations of dead material with bite weight and intake per minute for grazing horizon but not for the bottom layer. When the increase in dead material occurs in the grazing horizon, the animal probably becomes more selective for green material. As a consequence, bite size and intake per minute are reduced. Moore and Sollenberger (1986) observed lower bite weight and lower intake per minute when pastures of limpograss-aeschynomene were shorter and when there was a high proportion of dead material in the upper layer. Both studies suggest that animals actively avoided dead herbage present in the grazing horizon.

Weed percentage was negatively correlated with bites per minute in both layers (table 21). This influence did not have much effect on intake per minute. Perhaps dead material more than weeds has a negative influence on performance of animals grazing bahia-aeschynomene pastures.

It is evident from these results that legume and particularly legume leaf is the botanical component in bahia-aeschynomene pastures for which the animals selected. The presence of legume gave a

contrasting canopy structure and nutritive value to the pasture. The animal searched for more nutritious components in the canopy by making almost full use of its ingestive behavior mechanisms. Moore et al. (1985) suggested that dietary legume percentage of animals grazing limpograss-aeschynomene pastures was affected by different factors than those which affect total intake.

In bahiagrass pastures the canopy was relative consistent in its components and nutritive value. Consequently, animals were also quite consistent in their ingestive behavior. Only small changes in their ingestive behavior were required to maintain maximum intake of herbage available in the pasture.



## SUMMARY AND CONCLUSIONS

Introducing the legume *aeschynomene* into bahiagrass pastures increased herbage mass in the pastures. *Aeschynomene* also increased forage CP in the canopy grazing horizon by about 40%. The whole canopy forage IVOMD was depressed slightly (6%) by the introduction of the legume. Animals selected for a higher nutritive value diet in both pasture types. Animals obtained a 46% higher CP and only 6% lower IVOMD diet when grazing bahia-*aeschynomene* than when grazing bahiagrass pastures.

Bite weight obtained by animals grazing bahia-*aeschynomene* pastures was lower than that obtained from bahiagrass pastures. Intake per minute was not different, however, because in legume-grass pastures there was a higher biting rate which may have compensated for smaller bite weight. Bahia-*aeschynomene* pastures in the present study had an average of 15% legume in the canopy. The responses of the variables measured in the present experiment probably would change depending upon the percentage of legume in the pasture.

Herbage mass in bahiagrass and bahia-*aeschynomene* pastures was increased by managing the pastures in a rotational rather than in a continuous grazing system when both rotational and continuous pastures were grazed to 20 cm. Animal defoliation during rotational grazing reduced herbage mass to levels similar to those in continuously-grazed pastures.

Forage IVOMD in bahiagrass and bahia-aeschynomene pastures was also increased by managing the pastures rotationally. Even though animal defoliation reduced forage IVOMD during the rotational grazing period, the levels were still higher than those under continuous grazing. Part of this response was due to a reduction in the accumulation of dead material in the canopy of rotationally-grazed pastures.

By grazing the pasture rotationally animals consumed less weeds. Dead material was also consumed in lower percentage at the beginning of rotational grazing compared to that during continuous grazing.

Animals were able to consume a higher CP diet at the beginning of the rotational grazing period than when they were under continuous grazing. Animals consumed a higher IVOMD diet when under rotational grazing than when under continuous grazing.

Rotational grazing allowed animals to obtain a large bite weight at the beginning of the grazing period. This advantage, however, disappeared at the end of the grazing period when levels were similar to those found under continuous grazing. Due to the positive relationship between bite weight and intake per minute, animals at the beginning of the rotational grazing period obtained a high intake per minute. A depression in the rate of biting of animals after rotational grazing, however, depressed intake per minute to levels even lower than those found under continuous grazing. The data indicated that the presence of legume in bahia-aeschynomene pastures may override some of the depression in biting rate at the end of rotational grazing periods. Depression in bite rate at the end of rotational grazing periods may

have been due to an effect of the fresh trailing and soiling of the forage during the grazing period.

Also, managing the pastures rotationally allowed a higher percentage of grass in bahiagrass pastures and a higher accumulation of legume in bahia-aeschynomene pastures. The higher legume percentage in bahia-aeschynomene pastures was accompanied by a higher forage CP in the pasture at the beginning of the rotational grazing period.

In conclusion, the data indicated that the introduction of the legume aeschynomene in a bahiagrass pasture might increase the herbage mass available and the nutritive value of the forage for summer grazing animals. Managing bahiagrass and, particularly, bahia-aeschynomene pastures in a rotational grazing system favored a more desirable canopy structure and forage nutritive value for a higher diet nutritive value and intake. The more desirable canopy characteristics, however, might disappear at the end of rotational grazing periods with a negative effect on animal response.

A careful grazing management strategy is suggested if bahia-aeschynomene pastures are to be managed in a rotational grazing system. More efficient animals or animals of higher nutritional requirements should graze first during the rotational grazing period. It might not be a benefit at all if these animals are allowed to graze the pastures during the entire period. Animals will have the opportunity for a higher intake of a forage of higher nutritive value before all the legume is defoliated from the pasture. So, maximum benefit will be obtained if animals are removed to a new paddock before total defoliation of the legume. Other animals of lower nutritional needs

might graze the remaining forage. A biological response is foreseen if bahiagrass and particularly bahia-aeschynomene pastures are grazed rotationally rather than continuously. The more complicated management, however, deserves economical considerations that were not among objectives of the present study. Type of production system and marketing characteristics of a specific location surely have an impact on the economical returns of more complicated grazing systems.

The Florida livestock industry has calves and lactating cows, efficient animals in terms of weight gain, that might benefit as first grazers of the grazing system. Strategies of how such a grazing system would fit within the whole management system of a ranch need to be designed or investigated. There is a potential benefit to the beef industry in Florida in the use of this grass-legume association if management is done as indicated by the results of the present experiment. Uncertainty of such a system, like in many other agricultural activities, has to be expected if weather conditions are not adequate to obtain a good stand of aeschynomene.

## APPENDIX

Table 22 Analysis of variance for whole canopy herbage mass, height and botanical composition (MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. b	Herbage mass		Canopy height		Grass		Other <sup>c</sup>	
		MS	P	MS	P	MS	P	MS	P
Type (T)	1	1445494	.006	0.62	.762	7268.6	.001	1145.7	.001
Management (M)	2	1626112	.002	605.73	.001	1155.2	.001	2049.3	.001
T*M	2	253382	.124	8.38	.328	393.5	.001	125.8	.061
Error a									
Rep(T*M)	6	83941		6.20		15.2		27.2	
Cycle (CY)	3	283153	.001	53.38	.001	2528.9	.001	2006.2	.001
CY*T	3	207634	.001	7.53	.012	52.9	.091	153.1	.001
CY*M	6	303341	.001	49.57	.001	5.4	.950	2.9	.982
CY*T*M	6	168505	.001	3.27	.102	45.8	.094	55.3	.024
Error b									
Remainder	18	23048		1.24		21.0		16.9	
Total	47								

<sup>a</sup> Rep=replicate

<sup>b</sup> Degrees of freedom

<sup>c</sup> Other=weeds and dead material

Table 23 Analysis of variance for  
whole canopy legume  
percentage in bahia-  
aeschynomene pastures  
(MS=mean square;  
P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Legume	
		MS	P
Management (M)	2	331.1	.081
Error a Rep(M)	3	51.0	
Cycle (CY)	3	309.5	.001
CY*M	6	5.4	.586
Error b Remainder	9	6.7	
Total	23		

<sup>a</sup> Rep=replicate

<sup>b</sup> Degrass of freedom

Table 24 Analysis of variance for whole canopy  
nutritive value (MS=mean square;  
P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Crude protein		IVOMD <sup>c</sup>	
		MS	P	MS	P
Type (T)	1	16.08	.012	112.8	.054
Management (M)	2	11.73	.015	155.9	.021
T*M	2	5.04	.080	22.8	.376
Error a Rep(T*M)	6	1.27		19.7	
Cycle (CY)	3	1.33	.036	243.3	.001
CY*T	3	7.68	.001	9.9	.383
CY*M	6	0.66	.167	11.0	.355
CY*T*M	6	2.72	.001	9.9	.416
Error b Remainder	18	0.38		9.2	
Total	47				

<sup>a</sup> Rep=replicate

<sup>b</sup> Degrees of freedom

<sup>c</sup> IVOMD=in vitro organic matter digestion



Table 25 Analysis of variance for canopy layer herbage mass, and botanical composition (MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Herbage mass		Grass leaf		Grass stem	
		MS	P	MS	P	MS	P
Type (T)	1	1148688	.001	11855.7	.001	45.98	.124
Management (M)	2	171882	.044	1584.7	.001	7.47	.620
T*M	2	187133	.038	863.1	.004	7.06	.635
Error a Rep(T*M)	6	31396		53.0		14.39	
Layer (L)	1	4278807	.001	1699.3	.001	32.89	.144
T*L	1	249284	.005	484.9	.001	30.99	.154
M*L	2	8351	.565	14.1	.245	5.15	.662
T*M*L	2	1786	.877	97.8	.007	4.82	.679
Error b Rep*L(T*M)	6	13272		7.8		11.65	
Cycle (CY)	2	76126	.016	2508.3	.001	39.56	.062
CY*T	2	43900	.078	255.2	.011	37.31	.071
CY*M	4	18122	.348	50.2	.392	7.00	.697
CY*T*M	4	11598	.568	67.3	.252	6.64	.717
CY*L	2	12378	.461	62.0	.284	27.61	.134
CY*T*L	2	5519	.704	133.0	.078	26.02	.149
CY*M*L	4	10109	.630	64.6	.270	5.19	.799
CY*T*M*L	4	18092	.349	26.5	.690	4.89	.815
Error c Remainder	24	15463		46.8		12.61	
Total	71						

<sup>a</sup> Rep=replicate; only cycles 2, 3, and 4 are included

<sup>b</sup> Degrees of freedom

Table 26 Analysis of variance for canopy layer  
botanical composition (MS=mean  
square; P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Weeds		Dead material	
		MS	P	MS	P
Type (T)	1	315.3	.144	76.9	.215
Management (M)	2	97.2	.465	2551.9	.001
T*M	2	13.7	.886	146.8	.091
Error a Rep(T*M)	6	111.6		39.9	
Layer (L)	1	563.2	.003	348.0	.001
T*L	1	2.4	.759	1.6	.707
M*L	2	2.3	.908	94.4	.015
T*M*L	2	18.7	.496	2.3	.804
Error b Rep*L(T*M)	6	23.6		10.2	
Cycle (CY)	2	60.8	.113	2403.2	.001
CY*T	2	282.1	.001	161.8	.007
CY*M	4	221.0	.001	92.8	.021
CY*T*M	4	70.8	.050	70.6	.055
CY*L	2	14.5	.574	100.8	.035
CY*T*L	2	146.0	.009	0.33	.987
CY*M*L	4	82.2	.030	27.8	.340
CY*T*M*L	4	17.1	.618	10.5	.805
Error c Remainder	24	25.4		26.1	
Total	71				

<sup>a</sup> Rep=replicate; only cycles 2, 3, and 4 are included

<sup>b</sup> Degrees of freedom

Table 27 Analysis of variance for canopy layer legume fractions, (MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Legume leaf		Legume stem	
		MS	P	MS	P
Management (M)	2	120.4	.030	374.8	.016
Error a Rep(M)	3	8.6		16.9	
Layer (L)	1	357.5	.001	580.5	.012
M*L	2	85.5	.002	89.5	.125
Error b Rep*L(M)	3	1.0		19.9	
Cycle (CY)	2	143.8	.001	668.0	.001
CY*M	4	17.6	.037	30.0	.223
CY*L	2	54.5	.002	167.8	.004
CY*M*L	4	14.1	.068	5.2	.883
Error c Remainder	12	4.9		18.2	
Total	35				

<sup>a</sup> Rep-replicate; Only cycles 2, 3, and 4 are included

<sup>b</sup> Degrees of freedom

Table 28 Analysis of variance for canopy layer nutritive value (MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Crude protein		IVOMD <sup>c</sup>	
		MS	P	MS	P
Type (T)	1	71.78	.001	128.91	.076
Management (M)	2	26.42	.006	322.06	.009
T*M	2	4.70	.177	31.24	.388
Error a Rep(T*M)	6	2.01		28.06	
Layer (L)	1	55.42	.001	6.99	.124
T*L	1	19.58	.001	11.23	.064
M*L	2	8.38	.001	28.95	.006
T*M*L	2	2.95	.016	8.70	.079
Error b Rep*L(T*M)	6	0.33		2.18	
Cycle (CY)	2	3.34	.002	416.00	.001
CY*T	2	16.26	.001	34.75	.016
CY*M	4	1.70	.011	28.34	.012
CY*T*M	4	2.73	.001	19.4	.051
CY*L	2	1.60	.034	6.92	.389
CY*T*L	2	1.47	.043	6.80	.395
CY*M*L	4	0.17	.795	4.44	.645
CY*T*M*L	4	0.30	.585	1.49	.930
Error c Remainder	24	0.41		7.04	
Total	71				

<sup>a</sup> Rep=replicate<sup>b</sup> Degree of freedom<sup>c</sup> IVOMD=in vitro organic matter digestion

Table 29 Analysis of variance for grazing horizon herbage mass and botanical composition (MS=mean square; P=probability)

Source of variation <sup>a</sup>	d.f. b	Herbage mass		Grass leaf		Grass stem		Weeds	
		MS	P	MS	P	MS	P	MS	P
Type (T)	1	163869	.004	8568.0	.001	76.2	.137	131.1	.233
Management (M)	2	65925	.021	652.2	.004	12.5	.640	62.5	.478
T*M	2	104995	.005	657.7	.004	11.8	.656	0.57	.992
Error a									
Rep(T*M)	6	8336		40.6		25.9		74.6	
Cycle (CY)	2	42580	.132	1654.8	.001	66.6	.111	64.2	.192
CY*T	2	39652	.149	374.8	.023	62.8	.123	416.9	.001
CY*M	4	7885	.774	113.0	.244	12.1	.748	283.7	.002
CY*T*M	4	6535	.826	51.3	.598	11.5	.766	49.2	.278
Error b									
Remainder	12	17685		71.7		25.1		33.9	
Total	35								

<sup>a</sup> Rep-replicate; Only cycles 2, 3, and 4 are included

<sup>b</sup> Degrees of freedom

Table 30 Analysis of variance for grazing horizon dead material and forage nutritive value (MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Dead material		Crude protein		IVOMD <sup>c</sup>	
		MS	P	MS	P	MS	P
Type (T)	1	28.2	.292	83.17	.001	32.0	.134
Management (M)	2	1756.0	.001	32.28	.002	260.5	.001
T*M	2	65.0	.121	6.73	.063	9.4	.467
Error a Rep(T*M)	6	21.2		1.48		10.8	
Cycle (CY)	2	1678.9	.001	4.74	.001	262.1	.001
CY*T	2	86.3	.108	12.18	.001	29.3	.030
CY*M	4	73.8	.118	1.38	.034	18.2	.066
CY*T*M	4	36.5	.384	1.72	.017	12.1	.164
Error b Remainder	12	32.0		0.37		6.2	
Total	35						

<sup>a</sup> Rep=replicate; Only cycles 2, 3, and 4 are included

<sup>b</sup> Degrees of freedom

<sup>c</sup> IVOMD=in vitro organic matter digestion

Table 31 Analysis of variance for grazing horizon  
legume fractions (MS=mean square;  
P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Legume leaf		Legume stem	
		MS	P	MS	P
Management (M)	2	202.0	.010	411.5	.019
Error a Rep(M)	3	6.6		21.3	
Cycle (CY)	2	184.9	.002	723.2	.002
CY*M	4	30.3	.082	27.2	.566
Error b Remainder	6	8.9		33.9	
Total	17				

<sup>a</sup> Rep=replicate; Only cycle 2, 3, and 4 are included

<sup>b</sup> Degrees of freedom

Table 32 Analysis of variance for bottom layer herbage mass and botanical composition (MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. b	Herbage mass		Grass leaf		Grass stem		Weeds	
		MS	P	MS	P	MS	P	MS	P
Type (T)	1	1234103	.001	3772.6	.001	0.74	.032	186.6	.130
Management (M)	2	114308	.116	946.5	.001	0.12	.349	37.1	.573
T*M	2	83923	.180	303.1	.005	0.12	.360	31.8	.616
Error a									
Rep(T*M)	6	36333		20.2		0.09		60.6	
Cycle (CY)	2	45924	.065	915.6	.001	0.54	.061	11.0	.542
CY*T	2	9767	.499	13.4	.558	0.51	.069	11.1	.538
CY*M	4	20346	.254	1.8	.986	0.08	.719	19.6	.379
CY*T*M	4	23154	.204	42.5	.168	0.08	.736	38.7	.122
Error b									
Remainder	12	13241		21.9		0.15		17.0	
Total	35								

<sup>a</sup> Rep-replicate; Only cycles 2, 3, and 4 are included

<sup>b</sup> Degrees of freedom



Table 33 Analysis of variance for bottom layer dead material and forage nutritive value (MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>a</sup>	Dead material		Crude protein		IVOMD <sup>c</sup>	
		MS	P	MS	P	MS	P
Type (T)	1	50.2	.236	8.19	.021	108.1	.056
Management (M)	2	890.2	.001	2.52	.128	90.5	.060
T*M	2	84.2	.131	0.92	.398	30.5	.282
Error a Rep(T*M)	6	28.9		0.85		19.4	
Cycle (CY)	2	825.1	.001	0.20	.654	160.9	.001
CY*T	2	75.8	.054	5.56	.001	12.2	.253
CY*M	4	46.9	.116	0.49	.406	14.6	.185
CY*T*M	4	44.5	.130	1.31	.067	8.8	.400
Error b Remainder	12	20.2		0.45		7.9	
Total	35						

<sup>a</sup> Rep=replicate; Only cycles 2, 3, and 4 are included

<sup>b</sup> Degrees of freedom

<sup>c</sup> IVOMD=in vitro organic matter digestion

Table 34 Analysis of variance for bottom layer  
legume fractions (MS=mean square;  
P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Legume leaf		Legume stem	
		MS	P	MS	P
Management (M)	2	3.94	.396	52.8	.169
Error a Rep(M)	3	3.07		15.5	
Cycle (CY)	2	13.49	.009	112.5	.001
CY*M	4	1.47	.379	7.9	.098
Error b Remainder	6	1.16		2.5	
Total	17				

<sup>a</sup> Rep=replicate; Only cycles 2, 3, and 4 are included

<sup>b</sup> Degrees of freedom

Table 35 Analysis of variance for diet botanical composition (MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. b	Grass leaf		Grass stem		Weeds		Dead material	
		MS	P	MS	P	MS	P	MS	P
Type (T)	1	14663.7	.001	1.2	.591	310.3	.012	113.2	.054
Management (M)	2	21.3	.235	18.3	.061	109.3	.065	334.4	.003
T*M	2	317.2	.001	13.8	.099	34.8	.313	1.3	.936
Error a									
Rep(T*M)	6	11.4		4.0		24.6		19.7	
Cycle (CY)	3	411.5	.001	92.2	.001	119.5	.001	327.8	.001
CY*T	3	803.8	.001	13.7	.001	62.7	.002	19.6	.053
CY*M	6	101.3	.010	1.9	.342	29.4	.021	58.3	.001
CY*T*M	6	130.9	.003	5.2	.022	31.9	.015	21.8	.019
Error b									
Remainder	18	25.4		1.6		8.7		6.3	
Total	47								

<sup>a</sup> Rep=replicate

<sup>b</sup> Degrees of freedom

Table 36 Analysis of variance for diet legume fractions of animals grazing bahia-aeschynomene pastures (MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Legume leaf		Legume stem	
		MS	P	MS	P
Management (M)	2	1078.9	.034	55.1	.312
Error a Rep(M)	3	83.4		31.3	
Cycle (CY)	3	365.5	.001	1151.7	.001
CY*M	6	163.9	.006	39.4	.253
Error b Remainder	9	23.8		24.7	
Total	23				

<sup>a</sup> Rep=replicate

<sup>b</sup> Degrees of freedom

Table 37 Analysis of variance for diet nutritive value  
(MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Crude protein		IVOMD <sup>c</sup>	
		MS	P	MS	P
Type (T)	1	225.1	.003	221.9	.003
Management (M)	2	84.3	.015	47.3	.048
T*M	2	21.8	.171	26.4	.129
Error a Rep(T*M)	6	9.1		9.0	
Cycle (CY)	3	20.4	.001	74.5	.003
CY*T	3	19.6	.001	9.8	.478
CY*M	6	5.6	.001	12.2	.413
CY*T*M	6	5.9	.001	40.7	.016
Error b Remainder	18	0.82		11.3	
Total	47				

<sup>a</sup> Rep=replicate

<sup>b</sup> Degrees of freedom

<sup>c</sup> IVOMD=in vitro organic matter digestion

Table 38 Analysis of variance for animal ingestive behavior (MS=mean square; P=probability value)

Source of variation <sup>a</sup>	d.f. <sup>b</sup>	Bites/min		JMc /min		Bites/100JM		Bite size		Intake/min	
		MS	P	MS	P	MS	P	MS	P	MS	P
Type (T)	1	155.5	.014	50.4	.213	98.4	.223	0.05	.012	1.6	.658
Management (M)	2	423.4	.001	72.6	.139	615.3	.009	0.22	.001	782.4	.001
T*M	2	83.3	.033	57.6	.191	52.2	.427	0.003	.510	9.5	.348
Error <sup>a</sup> Rep(T*M)	6	13.1		26.0		53.2		0.004		7.5	
Cycle (CY)	3	119.3	.001	260.1	.003	541.1	.001	0.02	.008	30.5	.066
CY*T	3	47.5	.001	40.7	.385	190.8	.001	0.01	.059	44.1	.022
CY*M	6	29.6	.003	118.2	.029	127.3	.002	0.02	.008	28.5	.049
CY*T*M	6	45.3	.001	48.4	.317	52.2	.067	0.01	.134	34.2	.025
Error <sup>b</sup> Remainder	18	5.6		38.0		21.6		0.004		10.7	
Total	47										

<sup>a</sup> Rep-replicate<sup>b</sup> Degrees of freedom<sup>c</sup> JM=jaw movements

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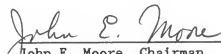
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#### BIOGRAPHICAL SKETCH

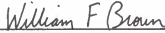
Jorge Luis Morales G. was born on July 30, 1951, in Cartago, Costa Rica. He graduated from Enrique Menzel High School, Turrialba, Costa Rica in 1969. In 1976 he started his professional studies at the University of Chihuahua, Mexico, and he graduated as a zootechnician engineer in 1979. He is married to Graciela Jimenez and has three children, Jorge, Diana and Jose Alonso.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

  
\_\_\_\_\_  
John E. Moore, Chairman  
Professor of Animal Science


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Associate Professor of Animal Science

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Harold H. Van Horn  
Professor of Dairy Science

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This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August 1990



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